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Antigravity Matter

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ABSTRACT

A new type of matter is defined that has positive mass but is affected by repulsive forces similar to the reverse of gravity. This is referred to as "Antigravity Matter". Its behaviour is investigated and some effects it would have on normal matter objects are predicted. Various phenomena that are currently commonly attributed to gravitationally attractive dark matter are found to be consistent with the predicted effects of Antigravity Matter. Other phenomena that are not commonly associated with dark matter are also found to be consistent with the predicted effects of Antigravity Matter.

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1. INTRODUCTION

Many strange gravitational phenomena have been observed in space. The dominant theory attributes these to the presence of gravitationally attractive cold dark matter. (Peebles 1982; Bond et al. 1982; Blumenthal et al. 1982, 1984). Others suggest that there is no gravitationally attractive dark matter but the behaviour of gravity changes with distance. This idea is referred to as MOND. (Milgrom 1983)

This paper investigates the hypothesis that these apparent gravitational phenomena are actually caused by a novel type of matter that is affected by a repulsive force instead of gravity. This is referred to as "Antigravity Matter" and as "AGM".

This paper investigates the following phenomena that are commonly associated with theories of dark matter:-

1. Spiral galaxies appear to be rotating too quickly for the gravity of their visible matter to hold them together. (Kapteyn 1922; Rubin & Ford 1970; Rubin et al. 1980; Corbelli & Salucci 2000).

2. Many spiral galaxies appear to have a dark matter halo in space around them. (Rubin & Ford 1970; Rubin et al. 1980; Corbelli & Salucci 2000; Battaglia et al. 2005)

3. The amount of apparent dark matter in spiral galaxies is highly variable. The mass-to-light ratio can vary by a factor of about ten. (Salucci et al. 1991)

4. The dark matter content of elliptical galaxies is far less variable than spiral galaxies and has been estimated at about 80% of the mass of the visible matter. (Magain & Chantry 2013)

5. Unlike spiral galaxies, elliptical galaxies do not appear to have halos of dark matter in space around them. As far as can be detected their apparent dark matter is co-located with their visible matter. (Magain & Chantry 2013)

6. Although dark matter is supposed to be affected by gravity it does not appear to collapse to create dense objects like normal matter does. It appears to remain at low density.

7. Anisotropies have been detected in the Cosmic Microwave Background ("CMB"). (Torbet et al. 1999; Melchiorri et al. 2000; Hanany et al. 2000) Regular periodic fluctuations in the density of normal matter have been detected in the present universe referred to as the Baryonic Acoustic Oscillation ("BAO"). (Eisenstein et al. 2005) These have both been attributed to processes in the developing universe that involved gravitationally attractive dark matter.

8. The apparent mass distribution of two galaxy clusters are difficult to explain using theories of gravitationally attractive matter. (Taylor et al. 1998; Clowe et al. 2004)

9. Many attempts have been made and are being made to detect dark matter directly by means that do not depend on gravity. However no conclusive detections have been made.

We also investigate other phenomena that are not conventionally associated with dark matter. These are:-

1. Bok globules. Bok globules are small molecular clouds. (Bok & Reilly 1947) They are typically a few light years in diameter and contain a few solar masses of cold gas and dust. They are relatively dense and usually have particularly clearly defined surfaces and a globular appearance. We investigate the appearance, density and radius of Bok globules.

2. Globular clusters. Globular clusters are dense collections of stars usually orbiting around a galaxy. We investigate the density, radius and location of the Milky Way's globular clusters.

3. Pulsar kicks. Pulsars are the remnants of a star created following a supernova. Following the supernova the pulsar is sometimes kicked away at high speed. (Cordes et al. 1993; Chatterjee & Cordes 2002) In this paper we investigate the shape of molecular clouds associated with a kicked pulsar, and the locations of pulsars.

Some theories of gravity allow for the existence of negative gravity (Zachos 1978; Scherk 1979; Linde 1980). Sanders (1986) has proposed that antigravity could be the basis of an explanation for the dark matter problem. However objections to that proposal have been raised by Goldman (1986). These objections are discussed in Section 5.

The Antigravity Matter hypothesis has been developed progressively between 2006 and 2014 at www.preston.u-net.com/AGMatter/Index.htm and since 2014 at http://www.antigravitymatter.co.uk.

2. THE ANTIGRAVITY MATTER HYPOTHESIS

In this section we explore the hypothesis that there is no significant amount of gravitationally attractive dark matter in the universe. Instead the universe contains a large amount of Antigravity Matter.

2.1. *Hypothesis*

Antigravity Matter has the following characteristics:-

- Antigravity Matter consists of particles that have positive mass and inertia.
- Particles of Antigravity Matter are repelled from each other. Particles of Antigravity Matter and normal matter objects are also repelled from each other. These repulsive forces are referred to in this paper as "Antigravity". Antigravity replaces conventional gravity between the affected objects.
- The strength of these repulsive forces is proportional to the masses of the affected objects, and follows the inverse square law with respect to the separation distance of the objects.
- Normal matter particles and Antigravity Matter particles rarely interact apart from via Antigravity.
- Electromagnetic radiation is diverted away from Antigravity Matter but does not otherwise interact with it. Electromagnetic radiation is affected by Antigravity to the same degree that normal matter is.
- Antigravity Matter has existed since shortly after the beginning of the universe.

The following initial deductions and assumptions are made from the hypothesis above:-

- Antigravity Matter has spread out to form a thin, approximately constant density atmosphere throughout most of interstellar and intergalactic space. However this atmosphere is repelled by normal matter, and there is therefore little or no Antigravity Matter near the Sun or near any other star.
- The deep space Antigravity Matter atmosphere behaves like a conventional theoretical ideal gas. It has the bulk properties of density, temperature and pressure. These can affect its behaviour in addition to its momentum and the forces of Antigravity.
- Because of the expansion of the universe most of the Antigravity Matter atmosphere has a very low temperature and pressure however when it is disturbed it can get hot.
- The Antigravity Matter atmosphere behaves like an ideal monatomic gas with $\gamma = \frac{5}{3}$.

No attempt is made to characterise the forces of Antigravity beyond the classical approach above. We do not propose a relativistic or quantum mechanical formulation. Antigravity may or may not be caused by a mechanism related to that which causes gravity.

In a gravity field free normal matter particles accelerate in the opposite direction to free Antigravity Matter particles relative to the source of the field. However in an Antigravity field free normal matter particles and free Antigravity Matter particles accelerate in the same direction relative to the source. Therefore Antigravity is not exactly the reverse of gravity.

2.2. *Definitions and Assumptions*

In the following analysis we use the following definitions and assumptions.

- A_{n} = Constant for repulsion between normal matter and Antigravity Matter.
- A_{a} = Constant for Antigravity Matter to Antigravity Matter repulsion.

These are the Antigravity equivalents of the conventional gravitational constant G.

- D_{ab} = The deep space background density of the Antigravity Matter atmosphere.
- P_{ab} = The deep space background pressure of the Antigravity Matter atmosphere.

We start the analysis with the assumption that the pressure of the Antigravity Matter atmosphere is negligible because of its very low temperature. Later we investigate the effect of pressure.

There are several subsections below where we envisage a universe containing an Antigravity Matter atmosphere. In each case this universe is treated as a classical three dimensional space which is uniform in all directions. It is otherwise assumed to be like our own except as specified. The current rate of expansion of the universe is assumed to have negligible effect in the timescales of the discussion. All speeds of matter are non-relativistic.

The existence of a low temperature atmosphere in space does not imply a fundamental zero velocity reference frame in the universe. Low temperature Antigravity Matter particles have low velocity relative to other Antigravity Matter particles nearby.

2.3. *A Normal Matter Object in a Universe with an Antigravity Matter Atmosphere*

Consider a universe containing only a negligible pressure Antigravity Matter atmosphere and a single normal matter object M which is stationary relative to the Antigravity Matter atmosphere. Assume that all the matter in the universe is at equilibrium. The Antigravity Matter is spread out evenly throughout the universe except where it is affected by M. The local disturbance to the Antigravity Matter caused by M is symmetrical around M. The repulsion that M feels from the Antigravity Matter all around balances out and the result is that M feels nothing.

2.4. *A Second Normal Matter Object*

Now we introduce a second normal matter object N as shown in Figure 1 which is fixed in position relative to M. M and N are both stationary relative to the Antigravity Matter atmosphere. M and N both repel Antigravity Matter and cause a local reduction in density. These influences are negligible outside the two dotted perimeters. Each of these regions of reduced density is referred to as an "AGM Lacuna". That term is used throughout this paper to refer to

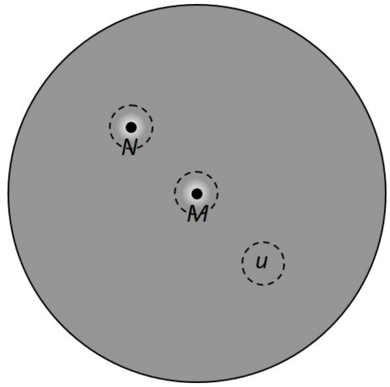

Figure 1. Normal matter objects M and N in a universe with an Antigravity Matter atmosphere. The density of Antigravity Matter is reduced close to the normal matter objects. This creates AGM Lacunas which can be treated as gravitationally attractive objects.

any region of space with a density of Antigravity Matter that is less than the background density D_{ab}. Since in this scenario all matter is equilibrium we also refer to it as a "Static AGM Lacuna".

The total force felt by M is made up of two components:-

1. M feels a conventional gravitational attraction towards N.

2. M feels a repulsion from all the Antigravity Matter throughout the universe. This almost completely balances out to zero. However the repulsion from some of the Antigravity Matter in the region of space marked u in Figure 1 remains unbalanced because of the AGM Lacuna around N. u is equidistant to N from M but in the opposite direction. The result is a force acting on M towards the AGM Lacuna around N.

The second component force above illustrates that the effect of an AGM Lacuna can be calculated by ignoring the Antigravity Matter throughout the universe and treating the AGM Lacuna as a gravitationally attractive object of equivalent mass and using the appropriate constant of Antigravity. This principle is used extensively in this paper and is referred to as "AGM Equivalence". It is demonstrated more rigorously in Section 2.12 below.

2.5. *The Antigravity Matter Density Profile around a Normal Matter Object*

We now consider how Antigravity Matter density varies within an AGM Lacuna around a normal matter object.

Consider a universe containing a single normal matter mass M and a negligible pressure Antigravity Matter atmosphere. M is stationary relative to the Antigravity Matter atmosphere. The density of Antigravity Matter is constant throughout the universe a large distance from M. The density profile is the same in all directions around M. We test the suggestion that close to M the density decreases smoothly as distance from M decreases.

Consider a small particle of Antigravity Matter of mass m at distance l from M. m feels a repulsion from M. Due to AGM Equivalence m also feels an attraction to the AGM Lacuna around M. However because of Newton's Shell Theorem and AGM Equivalence any reduction in density of Antigravity Matter at a radius greater than l will have no effect on m. The Antigravity Matter is at equilibrium so the force due to repulsion from M is equal to the force due to attraction to the AGM Lacuna.

Let the total reduction in Antigravity Matter mass inside a sphere of radius l be M_r.

$$\frac{M_r m A_a}{l^2} = \frac{M m A_n}{l^2} \tag{1}$$

$$M_r = \frac{M A_n}{A_a} \tag{2}$$

The Antigravity Matter mass reduction inside l is independent of l. If this is true for one particle at radius l then at any radius greater than l there cannot be any additional reduction in Antigravity Matter density. Hence with negligible AGM Pressure there must be a step change in the density of Antigravity Matter around the AGM Lacuna.

The location of this step change in Antigravity Matter density is referred to as the "AGM Boundary" of M.

2.6. *The Radius of a Normal Matter Object's AGM Boundary*

Continuing the analysis in Section 2.5 above, let the radius of the AGM Boundary be L_{b}. Since there is a step change in Antigravity Matter density:-

$$M_{\mathrm{r}} = D_{\mathrm{ab}} \frac{4}{3} \pi {L_{\mathrm{b}}}^{3} \tag{3}$$

Substitute in Equation 2:-

$$L_{\mathrm{b}} = \sqrt[3]{\frac{M A_{\mathrm{n}}}{D_{\mathrm{ab}} \frac{4}{3} \pi A_{\mathrm{a}}}} \tag{4}$$

2.7. *The Effect of Antigravity Matter on a small Normal Matter Object outside a large Object's AGM Boundary*

Continuing the analysis in Section 2.6 above consider a small normal matter object of mass N held at a fixed radius L outside the AGM Boundary of M where $N << M$. Assume that the effect of N's AGM Lacuna on N is negligible. N feels an attraction to M and an attraction to the AGM Lacuna within M's AGM Boundary. Let the total force on N be F. Due to AGM Equivalence:-

$$F = \frac{GMN}{L^2} + \frac{D_{\mathrm{ab}} 4/3 \pi {L_{\mathrm{b}}}^{3} N A_{\mathrm{n}}}{L^2} \tag{5}$$

Substitute Equation 4

$$F = \frac{GMN}{L^2} \left(1 + \frac{{A_{\mathrm{n}}}^{2}}{G A_{\mathrm{a}}}\right) \tag{6}$$

For example if $G = A_{\mathrm{n}} = A_{\mathrm{a}}$ the effect of the Antigravity Matter atmosphere is to double the apparent gravity of M outside M's AGM Boundary.

2.8. *The Effect of Antigravity Matter on a small Normal Matter Object inside a large Object's AGM Boundary*

We now change the situation in Section 2.7 above so that the small normal matter object N is inside M's AGM Boundary. Now N feels an attraction to M and an attraction to the portion of the AGM Lacuna that is within its radius L. This is due to Newton's Shell Theorem and the AGM Equivalence.

$$F = \frac{GMN}{L^2} + A_{\mathrm{n}} D_{\mathrm{ab}} \frac{4}{3} \pi L N \tag{7}$$

Figure 2 shows how the strength of the attractions that N feels vary with radius. Inside the AGM Boundary the attraction caused by the AGM Lacuna is proportional to radius. Outside the AGM Boundary the attraction caused by the AGM Lacuna is proportional to the gravitational attraction due to M.

2.9. *The AGM Exclusion Density*

So far we have considered the effect of point normal matter masses on the Antigravity Matter atmosphere. However the normal matter may be in a more distributed form such as the gas and dust in a molecular cloud or stars in a cluster. According to Newton's Shells Theorem outside a constant density spherical object its gravity acts as if all its mass is concentrated at the centre so the equations developed so far can still apply.

This leads to the concept of the "AGM Exclusion Density". This is the average density of normal matter within a volume that is just sufficient to exclude all of the Antigravity Matter from that volume. A first example of this is given by the mass of the normal matter object considered in Section 2.5 divided by the volume within its AGM Boundary.

Let the AGM Exclusion Density be D_{nx}. From Equation 2 and Equation 4

$$D_{\mathrm{nx}} = D_{\mathrm{ab}} \frac{A_{\mathrm{a}}}{A_{\mathrm{n}}} \tag{8}$$

In situations where the pressure of the Antigravity Matter atmosphere can be ignored the AGM Exclusion Density is independent of the mass of the normal matter object.

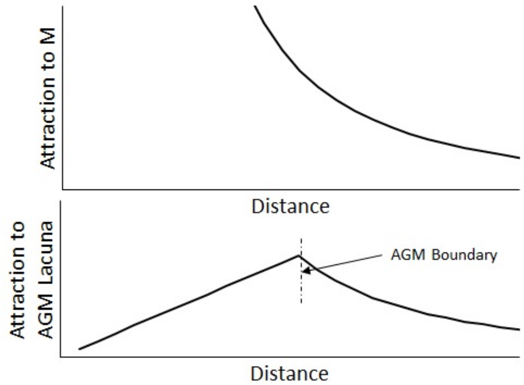

Figure 2. The profiles of the attractions that a small normal matter object feels towards a large normal matter object M and towards the AGM Lacuna within M's AGM Boundary. (With the assumption that the pressure of the Antigravity Matter atmosphere can be ignored)

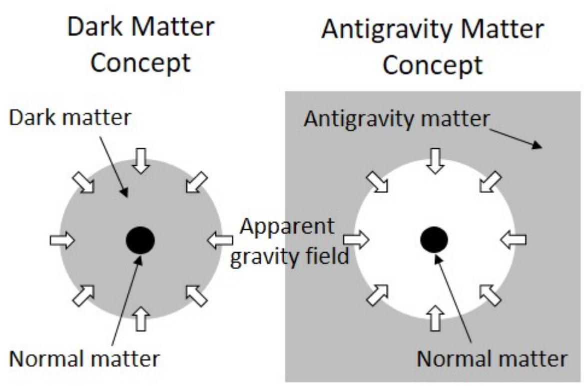

Figure 3. Comparison of gravitationally attractive dark matter and Antigravity Matter concepts. In the concept on the left dark matter is spread out close to the normal matter object. In the concept on the right Antigravity Matter is spread out throughout deep space but repelled from the normal matter object. Both concepts produce an apparent additional gravity field.

2.10. *Concept Comparison*

Figure 3 illustrates how Antigravity Matter could give the impression of the existence of gravitationally attractive dark matter.

In the universe on the right Antigravity Matter has formed a low temperature atmosphere throughout deep space with constant density except that it has been repelled from the central normal matter object to create an AGM Lacuna inside an AGM Boundary. Normal matter objects and electromagnetic radiation are attracted to the central normal matter object and to the AGM Lacuna. This produces a similar effect to the universe on the left in which a normal matter object is within a region of constant density gravitationally attractive dark matter.

2.11. *Antigravity Matter Pressure*

So far we have assumed that the pressure of the Antigravity Matter atmosphere is negligible because of its very low temperature. We now consider the behaviour of Antigravity Matter if the pressure of the Antigravity Matter atmosphere is not negligible.

Consider a universe containing a single normal matter object M and a well mixed Antigravity Matter atmosphere. They are stationary with respect to each other and at equilibrium. Within the Antigravity Matter atmosphere we identify a small volume of Antigravity Matter. It is at a radius l from M and has density ρ and pressure p. The pressure gradient at l is positive. Therefore the small volume of Antigravity Matter feels a buoyancy force from the Antigravity Matter around it pushing it inwards.

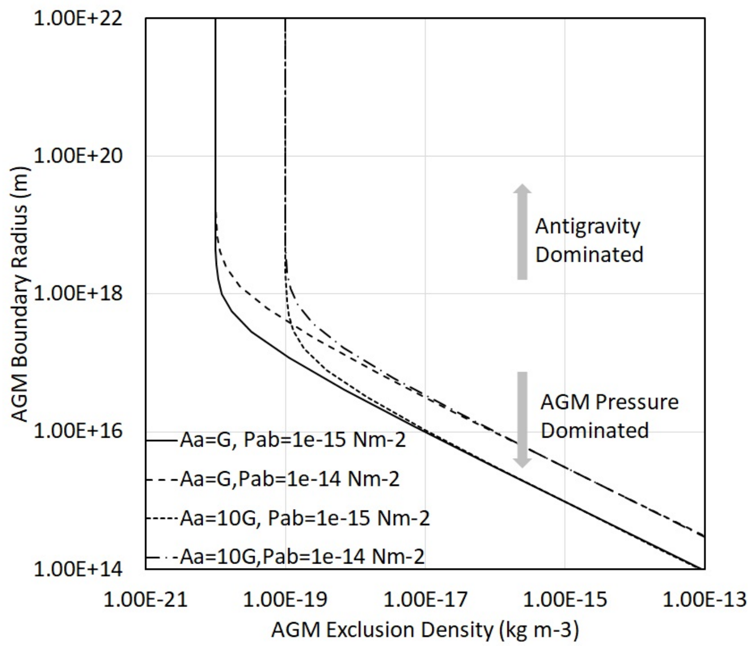

Figure 4. The variation of AGM Exclusion Density and AGM Boundary radius as the mass of a central normal matter object changes for various values of $\mathrm{A_a}$ and $\mathrm{P_{ab}}$. $\mathrm{A_n}$=G, $\mathrm{D_{ab}}=1\times10^{-20}\,\mathrm{kg\,m^{-3}}$

The repulsion it feels from M is equal to the attraction that it feels to the AGM Lacuna within radius l plus the buoyancy force inwards.

$$\frac{A_\mathrm{n}M}{l^2} = \frac{A_\mathrm{a}}{l^2}\left(\int_0^l (D_\mathrm{ab}-\rho)4\pi l^2 dl\right) + \frac{1}{\rho}\frac{dp}{dl} \tag{9}$$

We use an iterative computer algorithm to explore the relationship between the AGM Exclusion Density and the radius of the AGM Boundary for various values of $\mathrm{A_a}$ and $\mathrm{P_{ab}}$. The results are shown in Figure 4.

From Figure 4 it can be seen that Antigravity Matter has two behaviours when finding an equilibrium distribution around a normal matter object. When the radius of the AGM Boundary is low (and the mass of the normal matter object is low) the behaviour of the Antigravity Matter is dominated by its pressure and the effect of Antigravity between Antigravity Matter particles is negligible. When the radius of the AGM Boundary is high (and the mass of the normal matter object is high) the behaviour of the Antigravity Matter is dominated by Antigravity between Antigravity Matter particles and the effect of its pressure is negligible. In this latter condition the equations developed in Sections 2.2 to 2.9 are valid.

We refer to these two states as "AGM Pressure Dominated" and "Antigravity Dominated" respectively.

Therefore we can approximate the AGM Pressure Dominated behaviour by setting $\mathrm{A_a}$ to zero in Equation 9. The result is:-

$$\frac{A_\mathrm{n}M\,dl}{l^2} = \frac{dp}{\rho} \tag{10}$$

We have assumed adiabatic expansion so

$$p/\rho^\gamma = P_\mathrm{ab}/{D_\mathrm{ab}}^\gamma \tag{11}$$

$$\rho = (p/P_\mathrm{ab})^{1/\gamma}D_\mathrm{ab} \tag{12}$$

Therefore

$$\frac{A_\mathrm{n}M}{l^2}dl = \frac{{P_\mathrm{ab}}^{1/\gamma}}{D_\mathrm{ab}p^{1/\gamma}}dp \tag{13}$$

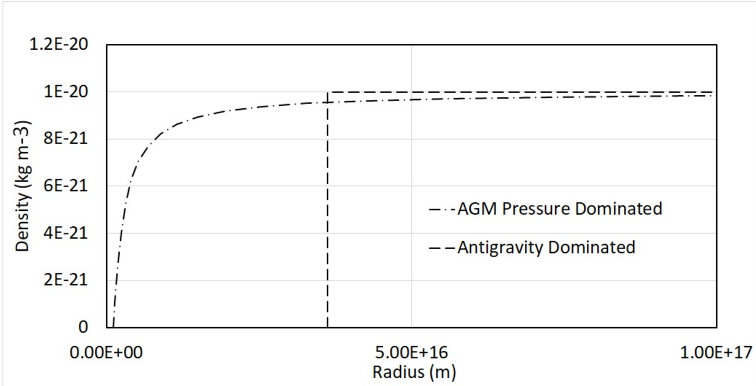

Figure 5. Example density profiles for Antigravity Matter around a central normal matter object, M. AGM Pressure Dominated and Antigravity Dominated cases are displayed with only P_{ab} varying between cases. $A_{\mathrm{a}} = A_{\mathrm{n}} = G$, $M = 2 \times 10^{30}\,\mathrm{kg}$, $D_{\mathrm{ab}} = 1 \times 10^{-20}\,\mathrm{kg\,m^{-3}}$. $P_{\mathrm{ab}} = 5 \times 10^{-16}\,\mathrm{N\,m^{-2}}$ or $P_{\mathrm{ab}} = 0\,\mathrm{N\,m^{-2}}$.

Integrate

$$\frac{-A_{\mathrm{n}}M}{l} = \frac{{P_{\mathrm{ab}}}^{1/\gamma}p^{(1-1/\gamma)}}{D_{\mathrm{ab}}(1-1/\gamma)} + C \tag{14}$$

When $l = \infty$, $p = P_{\mathrm{ab}}$

$$C = \frac{-P_{\mathrm{ab}}}{D_{\mathrm{ab}}(1-1/\gamma)} \tag{15}$$

At the AGM Boundary let $l = L_{\mathrm{b}}$, $p = 0$

$$L_{\mathrm{b}} = \frac{MA_{\mathrm{n}}D_{\mathrm{ab}}(1-1/\gamma)}{P_{\mathrm{ab}}} \tag{16}$$

When the Antigravity Matter behaviour is AGM Pressure Dominated the equilibrium radius of a normal matter object's AGM Boundary is proportional to the object's mass.

As before, let the AGM Exclusion Density = D_{nx}

$$D_{\mathrm{nx}} = \frac{P_{\mathrm{ab}}}{A_{\mathrm{n}}D_{\mathrm{ab}}(1-1/\gamma)4/3\pi {L_{\mathrm{b}}}^2} \tag{17}$$

$$L_{\mathrm{b}} = \sqrt{\frac{P_{\mathrm{ab}}}{A_{\mathrm{n}}D_{\mathrm{ab}}(1-1/\gamma)4/3\pi D_{\mathrm{nx}}}} \tag{18}$$

Equation 18 shows that when the Antigravity Matter is AGM Pressure Dominated $log(L_{\mathrm{b}})$ is proportional to $-0.5 \times log(D_{\mathrm{nx}})$ as M varies. This is consistent with Figure 4 and the results from the iterative computer assisted solution to Equation 9.

Also Equation 14 and Equation 15 give:-

$$p^{(1-1/\gamma)} = {P_{\mathrm{ab}}}^{(1-1/\gamma)} - \frac{MA_{\mathrm{n}}D_{\mathrm{ab}}(1-1/\gamma)}{l{P_{\mathrm{ab}}}^{1/\gamma}} \tag{19}$$

Equation 19 shows that in the AGM Pressure Dominated case there is not a step change of Antigravity Matter pressure and density at the AGM Boundary. Density increases more gradually as radius increases outside the AGM Boundary. However the assumption that $Aa = 0$ becomes more invalid with increasing radius. Equation 19 should only be used to assess the shape of the antigravity matter density profile close to the AGM Boundary.

Example Antigravity Matter density profiles for AGM Pressure Dominated and Antigravity Dominated cases are compared in Figure 5

Consider two Antigravity Matter particles which are both at the same long distance away from the central normal matter object in Figure 5, but one is in the AGM Pressure Dominated case and the other is in the Antigravity

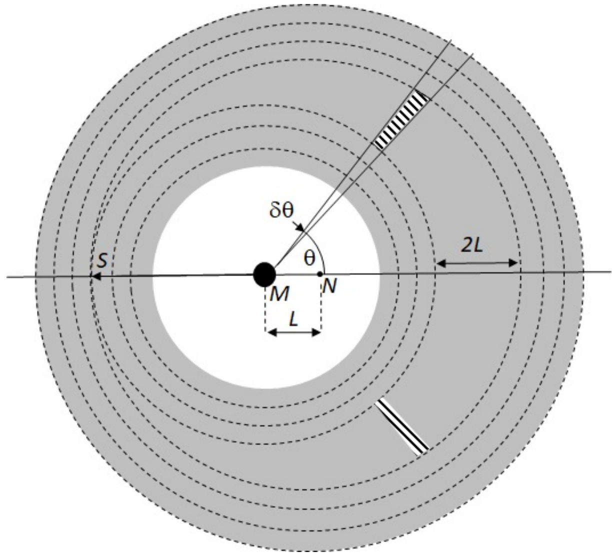

Figure 6. Concentric stacked shells of Antigravity Matter around M and N. (Not to scale)

Dominated case. At their location the Antigravity Matter pressure gradient is zero in both cases. For them both to be in equilibrium the total amount of Antigravity Matter removed by the AGM Lacuna must be the same in each case.

That is:-

$$\int_0^\infty (D_{\text{ab}} - \rho) 4\pi l^2 dl \tag{20}$$

is independent of Antigravity Matter pressure.

Therefore a long distance away from M the total apparent gravity of M is raised by a constant factor as shown in Equation 6 independent of whether the situation is AGM Pressure Dominated or Antigravity Dominated.

2.12. *A More Rigorous Explanation of AGM Equivalence*

Consider a small normal matter object N within a large normal matter object M's AGM Boundary. M and N are separated by distance L. This situation may be either AGM Pressure Dominated or Antigravity Dominated. The Antigravity Matter atmosphere is arranged around M in a spherically symmetrical manner. The Antigravity Matter atmosphere can be considered to be composed of a series of shells that are concentric with M and that are stacked all the way to infinity. Within each shell the density of Antigravity Matter is constant. From Newton's Shell Theorem the effect of each of these shells on N cancels out to zero. Therefore it could be argued that the Antigravity Matter atmosphere will have no effect on N. However in Section 2.8 we showed that it would have an effect given by the second term in Equation 7.

To rationalise these two arguments note that the shell at infinity is just as important to the analysis as any other shell. This is because the effect of any particle in a shell goes down with the square of distance , but the mass of the shell goes up with the square of distance. Infinity cannot be ignored just because it is a long way away.

Infinity can be dealt with by considering a set of shells concentric with N that stack inwards from infinity to a radius S that is much greater than L. This is shown in Figure 6. Within each of these shells the density of Antigravity Matter is constant because they are a long way away from M. The Antigravity Matter in these shells has no effect on N because they are concentric with N.

Now consider another set of shells that are concentric with M. These shells stack outwards until they meet the other shells at about radius S. From Newton's Shell Theorem we know that the Antigravity Matter in these shells has no effect on N. However there is now an asymmetric volume of Antigravity Matter atmosphere at about radius S that has not yet been accounted for. This Antigravity Matter has a net effect on N.

Let F be the total force on N due to the Antigravity Matter in that volume. Consider a portion of that volume that is a ring around the axis as shown in Figure 6. The ring subtends a half angle θ to the axis and its volume is defined by angle $\delta\theta$. The force on N due to the Antigravity Matter in the ring is δF. The density of Antigravity Matter in this volume is D_{ab} because it is a long distance from M.

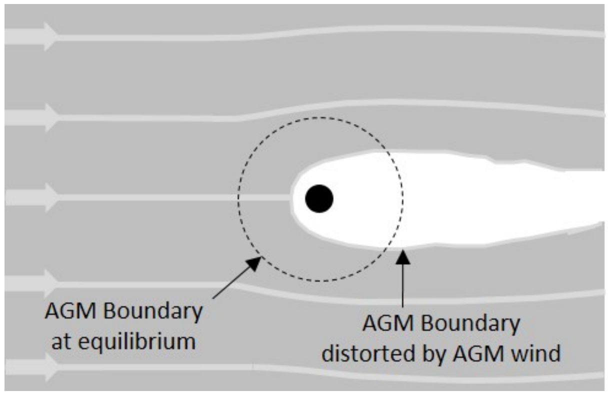

Figure 7. Antigravity Matter flowing around a normal matter object and distorting its AGM Boundary

$$\delta F = \frac{A_{\rm n} N \cos(\theta)}{S^2} D_{\rm ab} \times 2\pi S \sin(\theta) \times L(1+\cos(\theta)) \times S\delta\theta \tag{21}$$

$$F = A_{\rm n} N D_{\rm ab} 2\pi L \{ \int_0^\pi \sin(\theta)\cos(\theta) d\theta + \int_0^\pi \sin(\theta)\cos^2(\theta) d\theta \} \tag{22}$$

Note that this is based on the assumption that $S >> L$ but apart from that is independent of S. The first integral evaluates to zero. The second integral evaluates to $\frac{2}{3}$. Therefore:-

$$F = A_{\rm n} D_{\rm ab} \frac{4}{3} \pi L N \tag{23}$$

$$F = \frac{A_{\rm n} D_{\rm ab} \frac{4}{3} \pi L^3 N}{L^2} \tag{24}$$

Equation 23 is the same as the second term in Equation 7. Equation 24 demonstrates AGM Equivalence.

A similar argument can be deployed if N is outside M's AGM Boundary, and also if there is only a partial reduction in the density of Antigravity Matter within the AGM Lacuna. Hence the gravitational effect of any distribution of gravitationally attractive dark matter can be modelled as an Antigravity Matter atmosphere throughout the universe with one or more overlapping spheres of reduced density of Antigravity Matter. If a region of space has an apparent dark matter density of $D_{\rm k\text{-}apparent}$ then the equivalent Antigravity Matter density ρ is given by

$$\rho = D_{\rm ab} - \frac{G}{A_{\rm n}} D_{\rm k\text{-}apparent} \tag{25}$$

2.13. *Antigravity Matter Wind and Drag*

In all cases considered so far the normal matter objects have been stationary with respect to the Antigravity Matter atmosphere. Now consider a normal matter object M moving relative to the Antigravity Matter atmosphere as shown in Figure 7. The momentum of the Antigravity Matter wind drives the Antigravity Matter closer to M and distorts M's AGM Boundary. The density of the Antigravity Matter atmosphere is increased at the AGM Boundary's leading face. The Antigravity Matter atmosphere is dragged away from M and reduced in density at the AGM Boundary's trailing face. Therefore M feels a drag force mediated by Antigravity. Energy is transferred to the Antigravity Matter atmosphere where it takes the form of turbulence and heat.

The distribution of Antigravity Matter along the approach axis is likely to be complex with a shock wave if flow is supersonic. The location of the AGM Boundary on the approach axis can be approximated by replacing $\rm P_{ab}$ and $\rm D_{ab}$ in Equation 16 with the post-shock stagnation pressure and density of the Antigravity Matter wind.

Alternatively the location of the Antigravity Matter boundary on the approach axis can be approximated by considering only a single particle of Antigravity Matter and using a development of the conventional escape velocity equation. This developed equation is:-

$$L_{\text{b-closest}} = \frac{2A_{\text{n}}M}{(V_{\text{approach}})^2} \tag{26}$$

Where $L_{\text{b-closest}}$ is the radius of the AGM Boundary along the approach axis, and V_{approach} is the approach velocity of the Antigravity Matter wind a long way away from M.

In practical situations these two approaches give almost the same answer because in both cases all the energy of the distant approaching Antigravity Matter is converted to potential energy due to proximity to M at the AGM Boundary. The only difference between the two approaches is that the second ignores the heat energy of the distant Antigravity Matter atmosphere. As long as this is small compared to its kinetic energy the two approaches are equally valid. Both approaches ignore the potential energy reduction due to approach to the AGM Lacuna, but this is small as long as $L_{\text{b-closest}}$ is small compared to the radius of the theoretical zero pressure AGM Boundary.

If conditions are extreme and if M is not a point mass it is possible that the Antigravity Matter wind is not diverted completely and at least partly passes through M. Then another form of drag may occur when Antigravity Matter and normal matter particles occasionally collide.

2.14. *A Molecular Cloud and Antigravity Matter*

Consider the behaviour of a single, discrete molecular cloud in a universe that contains an Antigravity Matter atmosphere. We make the following additional starting assumptions:-

- The cloud is spherical.
- The cloud is so diffuse that on average it is below its AGM Exclusion Density. The cloud is not dense enough to exclude the Antigravity Matter from the volume that the cloud occupies. An AGM Boundary forms within the cloud around the denser center. Outside that boundary the normal matter gas and dust is mixed with the Antigravity Matter atmosphere.
- The Antigravity Matter does not exert any significant pressure on the cloud and vice versa.
- On short timescales the cloud is at equilibrium. It is well mixed. Its internal pressure is just sufficient to counteract the combined effect of Antigravity and gravity pulling it together.
- The cloud is moving slowly through the Antigravity Matter atmosphere. There is a slow flow of Antigravity Matter around the AGM Boundary within the cloud.

The Antigravity Matter atmosphere away from the cloud may be hot (perhaps heated by the flows within a galaxy as described later). However the Antigravity Matter close to the AGM Boundary has been adiabatically expanded so it is very cold. The normal matter gas near the AGM Boundary has also been adiabatically expanded and is also very cold. Because of rare particle level interactions the two can slowly exchange heat. Due to the flow of Antigravity Matter the Antigravity Matter cools the normal matter gas and dust. Also more energetic normal matter molecules move further into the Antigravity Matter atmosphere and are more likely to be transported away from the cloud by the flow of Antigravity Matter.

Given enough time the temperature of the cloud reduces. The heat of the cloud is transferred to the Antigravity Matter. It then diffuses out into the Antigravity Matter atmosphere in the rest of the universe.

As the cloud loses heat it becomes denser and drives more of the Antigravity Matter out of its volume. The normal matter in the cloud remains well mixed due to convention currents within. Eventually its average density gets up to its AGM Exclusion Density. At that point the normal matter and Antigravity Matter are no longer mixed. Heat transfer stops and the cloud becomes stable with an average density equal to its AGM Exclusion Density.

If any region of the cloud acquires more heat it expands, reduces in density, mixes with the Antigravity Matter atmosphere, loses its excess heat, and increases in density again.

A cloud in that state has a clearly defined surface when observed from a distance. That surface is the cloud's AGM Boundary.

If the cloud is Antigravity Dominated its density is defined by Equation 8. If the cloud is AGM Pressure Dominated its radius and density are related by Equation 18.

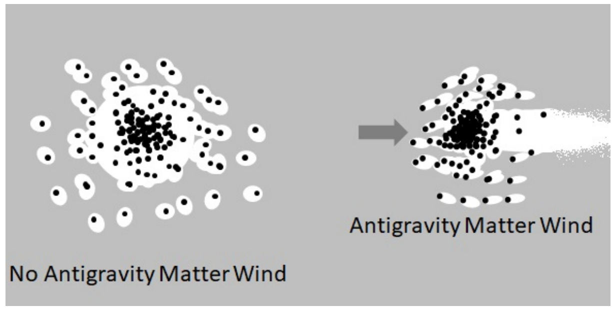

Figure 8. Wind drives Antigravity Matter closer to the center of a star cluster. Drag then makes the cluster more dense.

Consider such a stable molecular cloud that becomes affected by a strong Antigravity Matter wind. The Antigravity Matter is driven towards the centre of the cloud and passes through part of the cloud. The outer layer of the cloud is energised by occasional particle level collisions with the Antigravity Matter wind. It reduces in density, mixes even more with the Antigravity Matter and is eventually stripped away. The inner remnant of the cloud is denser and may be able to repel the wind and survive in the short term. However the turbulence of the wind affects its AGM Boundary, which disturbs the normal matter in the cloud. It is energised, reduces in density, mixes with the Antigravity Matter wind and is stripped away. Eventually the cloud is completely dispersed.

In the long term normal matter gas and dust ends up with low velocity relative to the Antigravity Matter atmosphere.

In Section 3.1 below we consider whether observations of Bok globules are consistent with the Antigravity Matter hypothesis.

2.15. *A Star Cluster and Antigravity Matter*

Consider a star cluster in a universe that contains an Antigravity Matter atmosphere. We make the following starting assumptions:-

- The cluster is approximately spherical.
- The cluster has dynamic stability. Stars are moving chaotically within the cluster. Some are falling inwards. Some are thrown outwards by interactions with other stars. Few stars acquire enough energy to escape from the cluster and few stars collide. Despite all this movement the cluster maintains approximately the same dimensions over short timescales.
- The stars are densely packed near the centre of the cluster but more widely separated away from the centre. A shared AGM Boundary has formed around the stars in the core of the cluster. These stars are on average at their AGM Exclusion Density. Stars outsided the shared AGM Boundary form AGM Boundaries of their own or in smaller groups.
- The centre of the cluster is stationary with respect to the Antigravity Matter atmosphere.

The stars within the shared AGM Boundary are not affected by Antigravity Matter drag. The stars outside the shared AGM Boundary are affected by drag. They lose energy and usually fall back into the cluster's core. The cluster gradually loses energy and becomes denser. The shared AGM Boundary gets bigger and the cluster gets smaller. As it shrinks within the shared AGM Boundary the rate of energy loss decreases.

The core's AGM Exclusion Density is defined by Equation 8 or Equation 18 depending on whether the cluster is Antigravity Dominated or AGM Pressure Dominated. If we assume that all such clusters are geometrically similar then they all eventually stabilise with their overall average density being approximately the same fraction of their AGM Exclusion Density.

Now we change the last assumption in order to consider the effect of the cluster moving through the Antigravity Matter atmosphere. The effect of Antigravity Matter wind is shown in Figure 8. The Antigravity Matter wind causes the pressure at the leading face of the cluster to increase. The Antigravity Matter is driven closer to the centre of the cluster. The Antigravity Matter atmosphere causes drag on the stars that pass through the distorted shared AGM Boundary and makes the cluster denser than it would be if there was no Antigravity Matter wind.

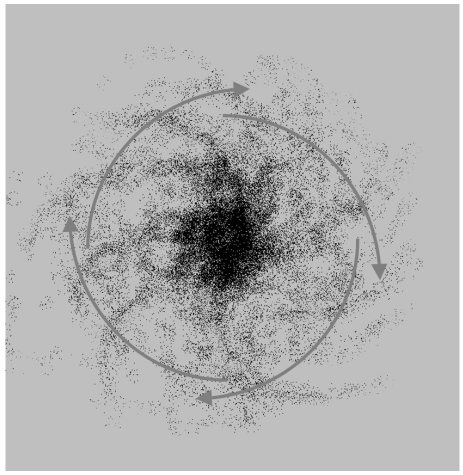

Figure 9. Within a spiral galaxy disc the Antigravity Matter (grey) is driven around the galaxy by the orbiting normal matter (black). The Antigravity Matter also flows outwards.

For a given velocity of Antigravity Matter wind the radius of the distorted shared AGM Boundary at the leading face is proportional to the mass of the core as shown by Equation 16. Therefore the radius of the core is proportional to the inverse square root of the density of the core. If we assume geometric similarity then the same relationship applies to the cluster's overall radius and density.

In Section 3.2 below we consider whether observations of the Milky Way's globular clusters are consistent with the AGM Hypothesis.

2.16. *A Spiral Galaxy Disc and Antigravity Matter*

Now we investigate the effect of the rotating disc of a spiral galaxy on the Antigravity Matter.

Consider a universe containing an Antigravity Matter atmosphere and the rotating disc of a spiral galaxy. Assume that the radius of a typical star's AGM Boundary is smaller than the average distance between neighbouring stars in the disc and that the Antigravity Matter atmosphere fills much of the space between stars in the disc.

We start the analysis by assuming that the Antigravity Matter is stationary with respect to the centre of the galaxy and its density is constant outside the Static AGM Lacunas of any stars or other normal matter objects. For Antigravity Matter particles the repulsion from the normal matter cancels out the attraction to the Static AGM Lacunas. As the galaxy disc rotates the stars pass through Antigravity Matter and are affected by a drag force. The reaction to the drag force acts on the Antigravity Matter and causes it to move. However unlike the normal matter objects in the disc, the Antigravity Matter does not initially feel any net attraction to the centre of the galaxy so it is swept outwards. This causes a reduction in density of the Antigravity Matter in interstellar space within the galaxy, an AGM Lacuna.

This AGM Lacuna attracts Antigravity Matter inwards towards the centre of the galaxy. Antigravity Matter above and below the disc near the axis of rotation flows inwards. Antigravity Matter in the disc follows a spiral path as it is swept outwards.

The density and flows of Antigravity Matter near a spiral galaxy are shown in Figure 9 and Figure 10. Some of the Antigravity Matter that has been swept outwards in the disc circulates back towards the axis of rotation away from the plane of the galaxy. Its angular momentum causes the region of rotation to extend along the axis of rotation away from the plane of the galaxy. The region of reduced density Antigravity Matter also extends away from the plane.

The Antigravity Matter in deep space close to the plane of the galaxy but far away from the galaxy is not affected by all this motion and yet it remains in equilibrium. Therefore the average density of Antigravity Matter in the volume of space containing the galaxy and all this motion at the start of this analysis is the same as the average density when the rotation has developed and the interstellar density in the centre has reduced. Therefore the Antigravity Matter that has been swept outwards forms a raised density region around the outside of the region of rotation. The outer region of increased density is referred to as the "Antihalo" of the galaxy.

The resulting flow pattern and density distribution is referred to as an "AGM Vortex". The AGM Lacuna caused by the AGM Vortex is referred to as a "Dynamic AGM Lacuna" to distinguish it from the Static AGM Lacuna in and around normal matter objects' AGM Boundaries.

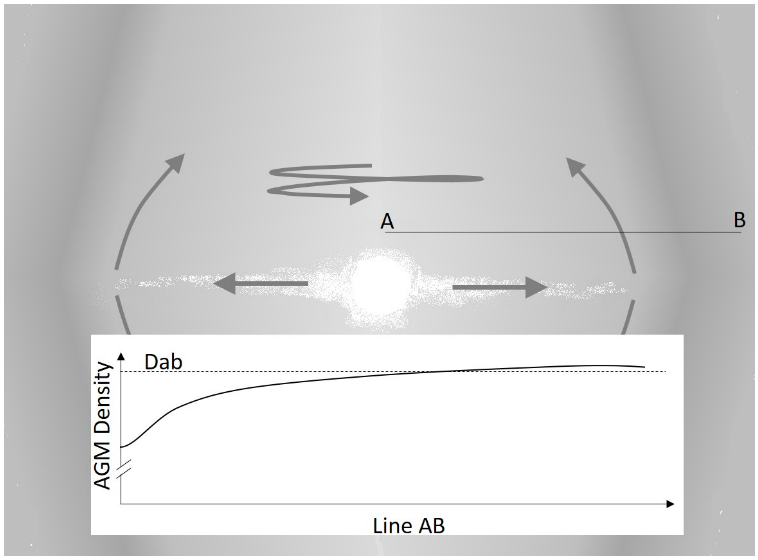

Figure 10. The flow and density profile of Antigravity Matter around a spiral galaxy. Denser regions are darker grey. AGM Lacunas are lighter grey or white. The AGM Vortex extends away from the galaxy along the axis of rotation. The Antigravity Matter that has been thrown outwards by the rotation builds up around the outside of the vortex.

A normal matter object orbiting a spiral galaxy is therefore influenced by several forces:-

- It is attracted to the other normal matter objects in the galaxy by gravity.
- It is attracted to the Static AGM Lacunas in and around the AGM Boundaries of the other normal matter objects.
- It is attracted to the Dynamic AGM Lacuna in interstellar space caused by the AGM Vortex. While this density reduction may be small the volume of space is large and the effect can be greater than the first two.
- It is affected by the Antigravity Matter at its own AGM Boundary. This causes a drag force pushing against the direction of movement relative to the local Antigravity Matter atmosphere.
- If it is within the galaxy and inside the Antihalo it is not affected much by the Antihalo. However if it is well away from the galaxy and outside the Antihalo the effect of the Antihalo cancels out the effect of the Dynamic AGM Lacuna caused by the AGM Vortex.

The last point offers a testable prediction. While there may appear to be a dark matter halo close to a spiral galaxy, well outside the galaxy (possibly a long way outside) the gravitational effects of part of the apparent dark matter halo will disappear.

We are not aware of any evidence for this around spiral galaxies. However in Section 3.8 below we assess whether observations of galaxy clusters are consistent with this prediction.

All this turbuence energises the Antigravity Matter particles so that in some places the Antigravity Matter atmosphere becomes hot. This helps to reduce its density futher. Hot Antigravity Matter tends to move towards the center of the galaxy. Antigravity Matter in the disc cools as it flows outwards.

2.17. *Orbital Velocity Profiles*

We consider how the Antigravity Matter density profile of an AGM Lacuna affects the orbital velocity of normal matter objects around the Dynamic AGM Lacuna. We simplify the calculation by treating the Dynamic AGM Lacuna caused by a spiral galaxy's AGM Vortex as being spherically symmetrical.

As an example the orbital velocities of normal matter objects within spiral galaxy discs are typically fairly constant over a wide range of radii. (Rubin et al. 1980) This is what gives the impression of there being a dark matter halo in space around the galaxy. For this to happen around an AGM Lacuna the density profile of the Antigravity Matter is defined by:-

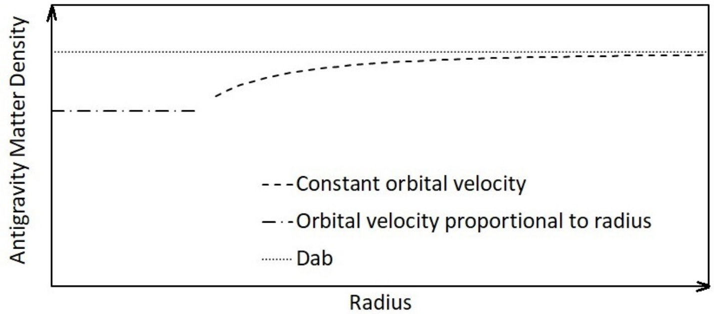

Figure 11. The forms of Antigravity Matter density profile that are required to give a normal matter orbital velocity that does not change with radius and a normal matter orbital velocity that is proportional to radius.

$$\rho = D_{\mathrm{ab}} - \frac{V^2}{A_{\mathrm{n}} 4\pi l^2} \tag{27}$$

where ρ is the density of Antigravity Matter at radius l and V is orbital velocity which is constant over a range of radii. Note that at very low radius this equation appears to demand a very large negative density of Antigravity Matter. That is clearly impossible. However that very large negative density is in a very small volume and its total attraction is finite because objects are in orbit at finite velocity. In reality at low radius orbital velocity is no longer constant and extra gravity is provided by a normal matter object in the centre according to Equation 6.

Figure 11 shows the typical form of this density profile. The general form of this curve is consistent with the density reduction in an AGM Vortex and consistent with a portion of the graph in Figure 10

In Section 3.5 below we show how this form of density profile can be derived for 2 example spiral galaxies with approximately constant orbital velocity .

Another example orbital velocity profile is for velocity to be proportional to radius. Within a region with such a profile there is no winding as objects orbit. Radial structures like galaxy bars can exist and persist.

For an object M in a circular orbit at velocity V and radius L, centripetal force F is governed by:-

$$F = \frac{MV^2}{L} \tag{28}$$

If F is proportional to L then V is proportional to L.

Figure 2 and Equation 7 show that the attraction to a spherical region of zero density Antigravity Matter is proportional to radius. In such a region the normal matter orbital velocity is proportional to radius. The same is true if the AGM Lacuna density profile is flat but non-zero. Again Figure 11 shows the typical form of this density profile.

In Section 3.6 below we explore an example galaxy whose density profile appears to be a combination of the two lines in Figure 11.

2.18. *A Spiral Galaxy Core and Antigravity Matter*

As described in Section 2.16 the stars orbiting in a spiral galaxy disc feel drag which causes their orbits to decay. They gradually get closer to the centre of the galaxy. The average density of normal matter at the centre of the galaxy increases. The normal matter displaces Antigravity Matter. An inner core forms. This is an approximately spherical region in the centre of the galaxy within which the stars are on average at their AGM Exclusion Density. A shared AGM Boundary forms around them.

Stars within the core's shared AGM Boundary are not affected by drag so they retain their cumulative kinetic and potential energy. They interact with each other through gravity and their movements are chaotic. Some stars gain enough energy to be expelled from the core. They form a lower density outer core outside the shared AGM Boundary. However outside the shared AGM Boundary they are affected by Antigravity Matter drag so most of them eventually lose energy and fall back inside the shared AGM Boundary.

The core gains energy and angular momentum as stars fall in from the galaxy disc, but loses energy and angular momentum by temporarily ejecting stars past the shared AGM Boundary.

Eventually all the stars fall into the core and the AGM Vortex dissipates. The spiral galaxy becomes a lenticular galaxy and then becomes an elliptical galaxy.

2.19. *Interstellar Molecular Matter and Antigravity Matter*

Gas and dust is injected into interstellar space by stars during and at the end of the lives. In a spiral galaxy's disc this material is cooled by the Antigravity Matter atmosphere as described in Section 2.14 and forms recognisable molecular clouds. Molecular clouds in the disc are swept outwards by the flow of Antigravity Matter as described in Section 2.16 until they eventually collapse and form new stars.

However gas and dust within the shared AGM Boundary of a spiral galaxy's core is not cooled by Antigravity Matter. It spreads out within the core and is stirred by the chaotic movement of the stars. It does not form recognisable molecular clouds or new stars unless it is ejected from the core.

This results in a higher proportion of younger stars in the outer regions of the disc than elsewhere in the galaxy.

In Section 3.4 below we assess whether observed spiral galaxies are consistent with this hypothesis.

2.20. *An Elliptical Galaxy and Antigravity Matter*

As described in Section 2.18 elliptical galaxies form when the disc of a spiral galaxy has fallen into the core. An elliptical galaxy does not have an AGM Vortex because it has little net rotation. Equation 6 shows that well away from a settled elliptical galaxy its total apparent gravity should be raised by a constant factor above the gravity that would be expected from its normal matter alone. It was shown in Section 2.11 that this is not affected by Antigravity Matter pressure and is therefore true whether the galaxy is AGM Pressure Dominated or Antigravity Dominated. All settled elliptical galaxies should follow this rule.

In Section 3.3 below we investigate whether observations of elliptical galaxies are consistent with this prediction.

2.21. *An Elliptical Galaxy Merger within an Antigravity Matter Atmosphere*

Consider two elliptical galaxies of approximately the same mass which are orbiting each other in a universe with an Antigravity Matter atmosphere. A large proportion of the stars are within shared AGM Boundaries within the two cores of the galaxies.

The galaxies each push through the Antigravity Matter atmosphere as they orbit. They create an AGM Vortex centred between them similar to that in Figure 9 and described in Section 2.16. However the profile of the AGM Lacuna is a little different to that in Figure 10. The rotation of the Antigravity Matter is driven at the radius of the orbiting galaxies. The angular speed of the Antigravity Matter atmosphere in the space in between them does not increase towards the centre. In the approximately spherical volume between the galaxies the Antigravity Matter density reduction is approximately constant. The density profile of the AGM Lacuna has the form of the two lines in Figure 11 combined.

The galaxies lose energy to drag. They get closer, orbit faster and the AGM Vortex gets stronger. Eventually the attraction of the AGM Lacuna between them is sufficient to disrupt the galaxies. They are distorted and then shredded by tidal effects and Antigravity Matter drag. Their stars are mixed with Antigravity Matter and form the disc of a new spiral galaxy.

However the break up process is uneven. Some dense groups of stars survive longer. These become globular clusters within the new spiral galaxy. Globular clusters continue to lose stars to Antigravity Matter drag as they orbit the new galaxy and eventually they disappear. They are temporary features even though they may contain old stars from the original elliptical galaxies.

Thus in Sections 2.16 and 2.18 we showed that spiral galaxies can become elliptical galaxies, and in this section we show that elliptical galaxies can become spiral galaxies. In Section 3.6 below we consider whether observations of an example spiral galaxy support this hypothesis.

2.22. *A Galaxy Cluster and Antigravity Matter*

A galaxy cluster is similar to a star cluster as described in Section 2.15 except that it's normal matter content is on average far less dense. Within a galaxy cluster the galaxies are not close enough to have created a shared AGM Boundary around many galaxies. There is therefore an Antigravity Matter atmosphere throughout intergalactic space within the cluster and throughout much of interstellar space within galaxies in the cluster.

The galaxies move rapidly in the cluster and disturb the Antigravity Matter atmosphere. If the cluster has a net rotation then the effect is similar to the AGM Vortex within a spiral galaxy described in Section 2.16. If the cluster

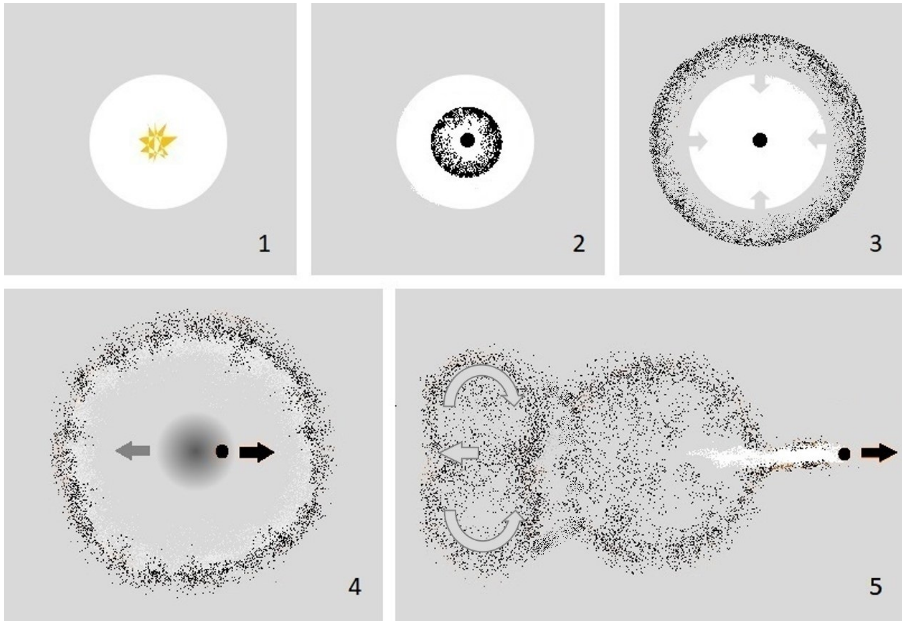

Figure 12. A process causing a pulsar kick in a universe with Antigravity Matter in which normal matter (black) is expelled from the pulsar in a spherical shell. Antigravity Matter is in grey. An example is shown in Figure 26.

has no net rotation then the movement of galaxies is chaotic. As they move towards and away from the center of the cluster they heat the Antigravity Matter and sweep it away from the center of the cluster. The density of Antigravity Matter in the cluster reduces. The intergalactic density reduction may be very small compared to D_{ab} or to the reduction caused by a spiral galaxy's AGM Vortex but the volume is very large. The displaced Antigravity Matter forms a higher density Antihalo around the cluster similar to that of a spiral galaxy described in Section 2.16.

The effect is that within the cluster and inside the Antihalo the apparent gravity field of the cluster is strengthened by the cluster's AGM Lacuna. However outside the Antihalo that apparent extra gravity of the cluster's AGM Lacuna is cancelled out.

In Section 3.8 below we assess whether two galaxy clusters are consistent with these predictions.

2.23. *Pulsar Kicks and Antigravity Matter*

Pulsars are the remains of a star created following a supernova. Following the supernova the pulsar is sometimes kicked away at high speed. (Cordes et al. 1993; Chatterjee & Cordes 2002) (http://www.astro.cornell.edu/~shami/guitar/ A process that causes this is described below.

Consider a universe with a star which is stationary with respect to the Antigravity Matter atmosphere. Both are at equilibrium. There is an approximately spherical AGM Boundary around the star.

Now consider that the star explodes in a spherically symmetrical manner and expels much of its mass in a rapidly expanding shell. A much smaller core is left at the centre, a pulsar. If the conditions are right the following process is possible which is described with reference to Figure 12.

Figure 12 panel 2. Straight after the explosion the AGM Boundary is unaffected by the explosion because the Antigravity of the expanding shell of expelled matter still acts as if all its mass is at the centre due to Newton's Shell Theorem, and because Antigravity Matter is not significantly affected by electromagnetic radiation. This situation continues until the expanding shell reaches the AGM Boundary.

Figure 12 panel 3. The expanding shell then passes through the AGM Boundary and into the Antigravity Matter atmosphere. Antigravity Matter particles rarely interact with normal matter so the shell continues to expand, decelerating gently due to Antigravity Matter drag. However due to Newton's Shell Theorem the Antigravity of the expanding shell has little effect on the Antigravity Matter that is now inside it. The mass of the remaining pulsar is no longer sufficient to support the previous AGM Boundary. The Antigravity Matter within the expanding shell falls inwards. As the shell continues to expand more Antigravity Matter falls inwards.

Figure 12 panel 4. Eventually a large amount of Antigravity Matter arrives at speed at the centre creating a temporary, localised spike in Antigravity Matter density. This occurs many years after the original explosion. Slightly asymmetries at the start cause the spike to occur mostly to one side of the pulsar. The core and the Antigravity Matter in the spike are repelled from each other violently and the core is kicked away from its original position at speed.

Figure 12 panel 5. A jet of Antigravity Matter is kicked away in the opposite direction. The core and the jet burst through the shell of expelled normal matter. The jet mixes with normal matter gas and dust. The jet interacts with the surrounding Antigravity Matter atmosphere and creates a toroidal vortex with a similar flow pattern to a smoke ring. The toroidal vortex expands as it moves into lower density Antigravity Matter. The inward flow of Antigravity Matter that is not in the jet stops the expelled shell of normal matter and maybe even brings it back inwards.

If there is an unknown mechanism by which the explosion heats the local Antigravity Matter atmosphere the inflow of Antigravity Matter is stronger. This is because substituting an increased pressure for P_{ab} in Equation 16 reduces the radius of the AGM Boundary.

Other versions of this processes exist for different starting conditions, in particular if the expelled material is not in a spherically symmetrical shell. This is described futher at www.antigravitymatter.co.uk.

In Section 3.9 below we consider whether an observed pulsar is consistent with this hypothesis.

2.24. *Cosmic Microwave Background*

A process for the development of anisotropies in the CMB has been proposed. (Peebles & Yu 1970; Harrison 1970; Zeldovich 1972; Doroshkevich et al. 1978) This process includes gravitationally attractive dark matter, as well as normal matter, photons and neutrinos. The process starts with slight overdensities of all four species in many small regions of space. Throughout the process the dark matter does not move significantly and does not significantly affect the other species. The process results in many overlapping spherical shells of slightly overdense normal matter, with overdense regions of gravitationally attractive dark matter at their centres. The overdense normal matter results in hotter regions of the CMB.

An alternative pre-recombination process with Antigravity Matter instead of gravitationally attractive dark matter starts with many regions that are overdense in Antigravity Matter, normal matter, photons and neutrinos. For the normal matter, photons and neutrinos the process continues in the same way.

Each overdense region of Antigravity Matter generates a spherical pressure wave moving outwards. However this wave is very slow compared to the normal matter/photon wave and by the time of recombination it has covered a very small distance compared to the radius of the shell of overdense normal matter. The overdense Antigravity Matter also repells the normal matter and Antigravity Matter that is ahead of the expanding wave. The Antigravity Matter ahead of the wave accelerates away. But the movement of normal matter is severely restricted due to its interaction with photons. By the time of recombination this results in a central region which contains a spherical shell of overdense Antigravity Matter surrounded by a spherical shell with reduced density of Antigravity Matter surrounded by a spherical shell with increased density of Antigravity Matter.

In these two versions of the process neither the gravitationally attractive dark matter nor the Antigravity Matter have a visible effect on the CMB. Therefore any measurements of the CMB that are consistent with a gravitationally attractive dark matter hypothesis are also consistent with the Antigravity Matter hypothesis.

2.25. *Development of the Universe's Structure After Recombination*

A process for the development of the structure of the universe after recombination and up to the present has been proposed. (Peebles & Yu 1970; Sunyaev & Zeldovich 1970) This process involves gravitationally attractive dark matter and follows on from the pre-recombination process described in Section 2.24. In this process the overdensities of normal matter and dark matter at recombination seed the development of galaxies as the universe cools. This process leads to the BAO because there is an increased probability of any randomly selected pair of galaxies being separated by a distance corresponding to the current radius of the spherical shells. This happens when one of the selected galaxies is in the centre and the other is in the shell.

An alternative post-recombination process with Antigravity Matter and without gravitationally attractive dark matter follows on from the alternative pre-recombination process described in Section 2.24. The process starts with many overlapping spherical shells of overdense normal matter with regions of overdense and underdense Antigravity Matter at their centres. The process is described below with reference to Figure 13.

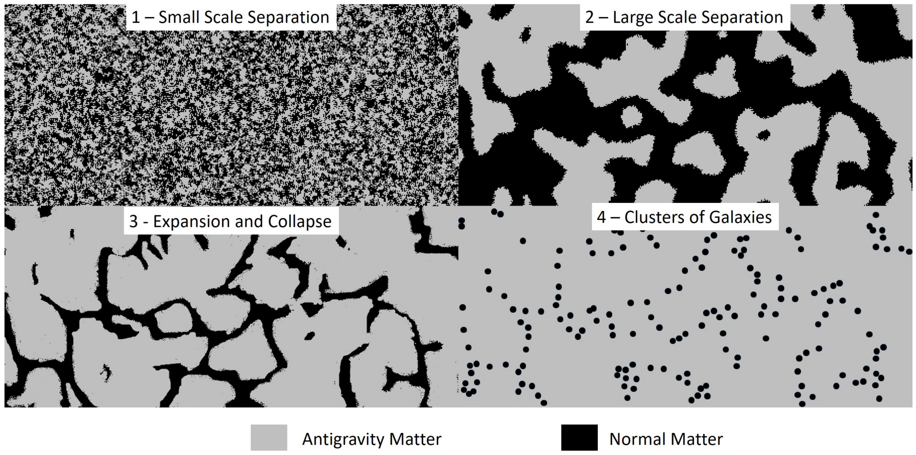

Figure 13. Stages of development of normal matter and Antigravity Matter structure in the early universe

Gravity and Antigravity cause normal matter to move towards regions of higher density of normal matter and away from regions of higher density of Antigravity Matter. Gravity and Antigravity cause Antigravity Matter to move away from regions of high density of anything. The result is that as the universe expands and cools normal matter and Antigravity Matter separate.

Initially the scale of the separation is small. That is, individual regions dominated by normal matter and Antigravity Matter are small. This is shown in Figure 13 panel 1.

The normal matter is still hot and gravity cannot collapse it because of its pressure. However gravity can still make regions dominated by normal matter coalesce. In time the regions dominated by normal matter and Antigravity Matter become large. This is shown in Figure 13 panel 2.

As the universe cools the normal matter dominated regions shrink under gravity. As the universe expands the Antigravity Matter dominated regions inflate until they became vast approximately spherical bubbles. This leaves the Antigravity Matter particles with little energy. Normal matter is swept into the spaces between the Antigravity Matter bubbles. This is shown in Figure 13 panel 3.

Eventually the normal matter cools and aggregates. The Antigravity Matter makes this happen quicker because the effective attraction between normal matter regions and objects is increased and because AGM drag reduces the energy of orbiting normal matter objects. This produces galaxies in clusters and formations of sheets and strings separated by vast approximately spherical spaces containing little or no observable matter. The scale of this structure is small compared to the scale of the BAO.

Antigravity pushes the normal matter together and Antigravity Matter drag reduces the energy of orbiting normal matter objects. These effects help the final step in the process to happen quickly. This is shown in Figure 13 panel 4.

Therefore this process with Antigravity Matter produces:-

- A higher probability of galaxies seeded from the spherical shells and from the centres of the shells, and a BAO signal with the same distance as the process with gravitationally attractive dark matter;
- A smaller scale structure consisting of galaxies in clusters and formations of sheets and strings separated by vast approximately spherical spaces containing little or no observable matter.

In Section 3.13 below we consider whether observations are consistent with this hypothesis.

3. EVIDENCE

This section describes several items of evidence and explains how they support the Antigravity Matter hypothesis.

3.1. *Bok Globules*

3.1.1. *Bok Globule Observations - Shape*

Bok globules are small molecular clouds that usually have a globular appearance and a clearly defined surface. (Bok & Reilly 1947)

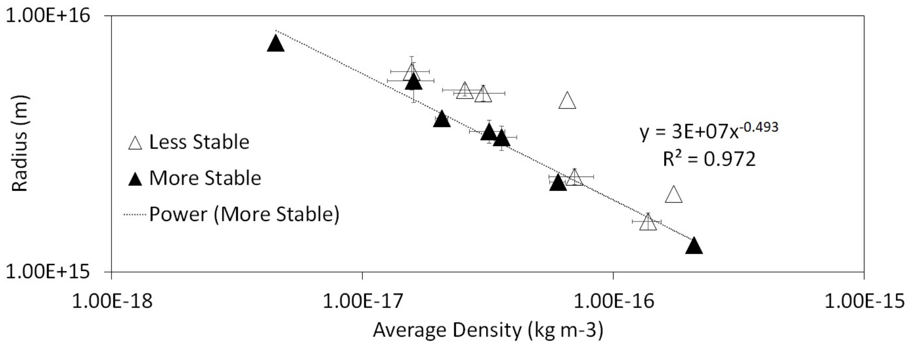

Figure 14. The relationship between Bok globule radius and density.

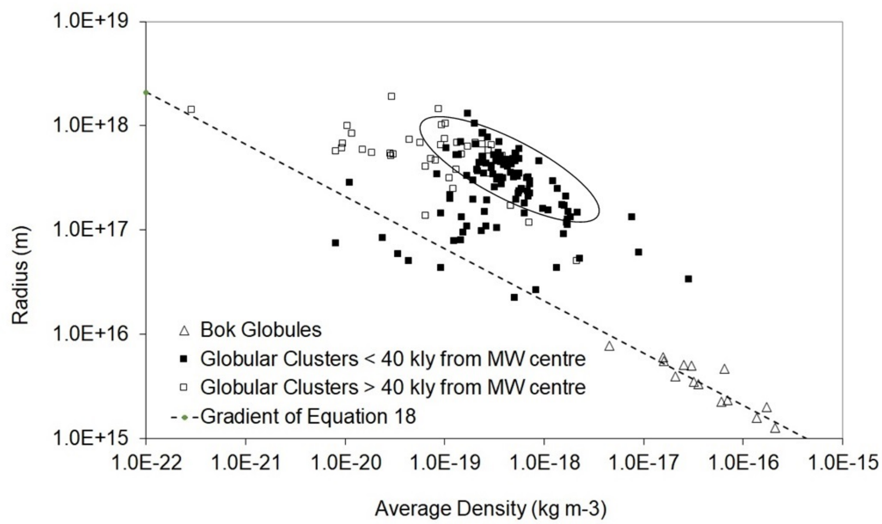

Figure 15. The relationship between radius and density of Bok globules and globular clusters.

3.1.2. *Bok Globule Observations - Radius-Density Relationship*

The characteristics of several visibly approximately circular Bok globules have been measured and analysed by Kandori et al. (2005). A number of assumptions are made in that work including:-

- The Bok globules can be treated as spherical objects.
- The observed data can be fitted to a Bonnor-Ebert model to estimate the distances and other parameters of the Bok globules.

To be consistent with that second assumption this analysis uses the mass and distance data from the second rows of Table 5 of that work. In Figure 5 of that work more stable Bok globules are idenified by their lower centre-to-edge density ratio.

The results of this analysis of the data from that work are plotted in Figure 14 and Figure 15. The more stable Bok globules are identified in Figure 14. The trend line applies to them only.

Figure 14 shows that for these Bok globules radius is approximately proportional to the inverse square root of average normal matter density. That is, mass is approximately proportional to radius, and density reduces as mass increases. We believe that this is the first publication of the observation of that relationship.

3.1.3. *Bok Globules Observations - Example Bok Globules*

Two Bok globules are shown in Figure 16. A higher definition image of one of these is available at http://www.galaxyphoto.com/high_res/hst_carina.JPG. In Figure 16 the two Bok globules appear to have two tails that look like

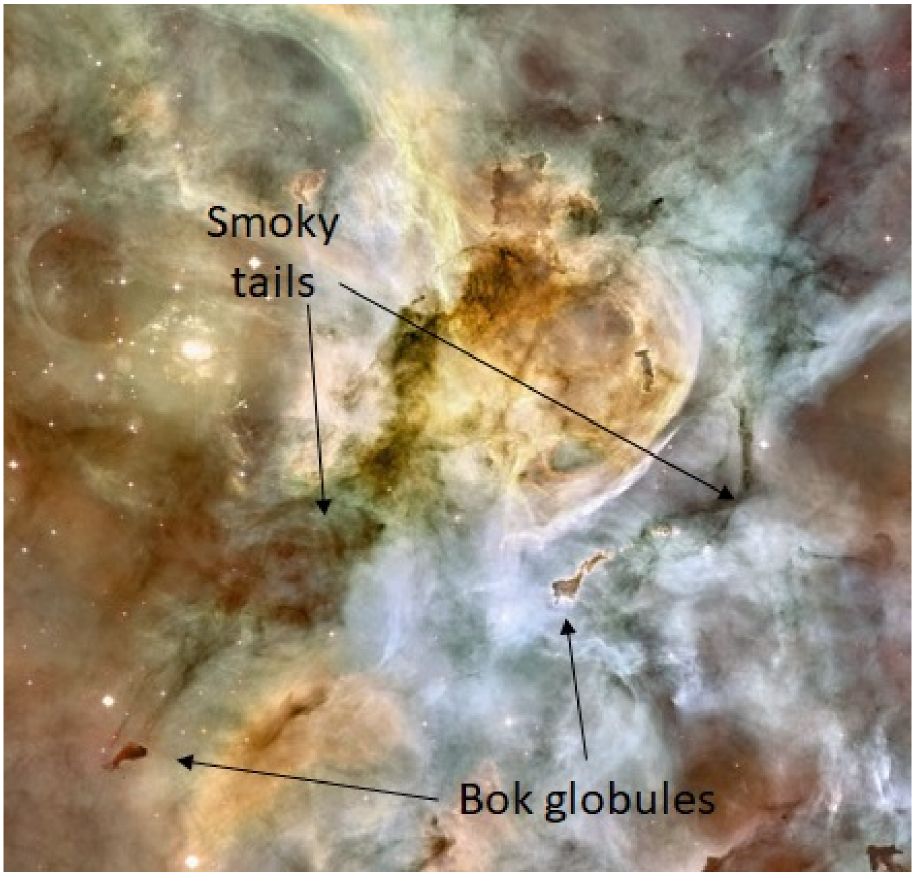

Figure 16. Example Bok Globules

smoke. The tails appear to have regions of laminar and turbuent flow. In the high definition image it can be seen that most of the Bok globule's surface is clearly defined but there are some regions where the surface is more diffuse.

3.1.4. *Antigravity Matter Based Explanation of Bok Globule Observations*

Bok globules do not usually move fast with respect to the Antigravity Matter atmosphere. They are at their AGM Exclusion Density. The visible surface of the Bok globule is its AGM Boundary. That is why they usually have a clearly defined surface and a globular appearance.

Bok globules are small enough to be AGM Pressure Dominated. The average density of their normal matter content is related to their radius by Equation 18. This relationship gives the gradient of the dashed line in Figure 14.

The description of the creation of a Bok globule in Section 2.14 implies that most Bok globules are well mixed. Convection currents cause turbulence, and pressure and temperature reduce with increasing distance from the center. This is inconsistent with the Bonner-Ebert model which assumes constant temperature throughout. However we assume the effect of this difference is small or at least consistent. Apart from that, fitting the observed data to a Bonner-Ebert model is appropriate because as described in Section 2.14 the Antigravity Matter atmosphere does not apply any significant direct pressure to the Bok globules.

Antigravity has little direct effect on the normal matter in the Bok globules compared to gravity because they are small and AGM Pressure Dominated.

For the more stable Bok globules in Figure 14 we can estimate that (using SI units throughout)

$$Radius = (2.2 \pm 0.6) \times 10^{7} \times Density^{-0.5} \tag{29}$$

$$Radius = (6.0 \pm 2.8) \times 10^{-16} \times Mass \tag{30}$$

where the confidence limits cover the range and the limits defined by Kandori et al. (2005) for the more stable Bok globules.

Substituting from Equation 29 into Equation 17 we can estimate that

$$\frac{P_{\mathrm{ab}}}{A_{\mathrm{n}} D_{\mathrm{ab}} (1 - 1/\gamma)} = (2.1 \pm 1.0) \times 10^{15}\,\mathrm{kg\,m^{-1}} \tag{31}$$

If we assume that γ is $\frac{5}{3}$ as for an ideal monatomic gas then

$$\frac{P_{\mathrm{ab}}}{A_{\mathrm{n}} D_{\mathrm{ab}}} = (8.4 \pm 3.9) \times 10^{14}\,\mathrm{kg\,m^{-1}} \tag{32}$$

The Bok globules in Fig 16 are moving relative to the Antigravity Matter atmosphere. They are in the process of being shredded by Antigravity Matter wind as described in Section 2.14. The smoky tails are the normal matter material that has been stripped from them by the Antigravity Matter wind. The smoky tails do not have a globular appearance because they consist of normal matter either mixed with Antigravity Matter or separated from Antigravity Matter on a scale that is too small to show in this image.

In the high definition image referenced above in Section 3.1.3 the regions with a diffuse surface are where normal matter is mixing with Antigravity Matter and is being stripped away by Antigravity Matter wind. The lumpiness of the leading face is consistent with the hypothesis that the Bok globule is being broken up by the Antigravity Matter wind.

Therefore the following observations are all consistent with the Antigravity Matter hypothesis:-

- The relationship between Bok globule radius and density shown in Figure 14 and Figure 15
- The globular nature of the surface of most Bok globules
- The diffuse nature of some normal matter gas and dust in situations that correspond with Antigravity Matter wind

We are not aware of an alternative explanation for the first of these.

3.2. *Globular Clusters*

3.2.1. *Globular Cluster Observations - General*

Globular clusters are relatively dense star clusters that usually exist within and around galaxies. Some of the stars in the Milky Way's globular clusters appear to be older than the Milky Way (Hansen et al. 2002).

3.2.2. *Globular Cluster Observations - Radius-Density Relationship*

Data on the Milky Way's globular clusters have been published at http://www.atlasoftheuniverse.com/globular.html. These data are analysed as follows. The mass of each globular cluster is estimated from the globular cluster's luminosity by assuming stars are on average like the Sun. The average density of each globular cluster is calculated from the mass and the radius. This is plotted in Figure 15.

Many globular clusters are in a tight group in Figure 15 which is ringed. This group shows a relationship between density and radius with a similar gradient on this log/log graph to that of the Bok globules. More massive globular clusters in the ringed group are less dense. There are several globular clusters outside and below the ring but there are no globular clusters outside the ring and above the ring and above the extrapolated line through it parallel with the dashed line.

3.2.3. *Globular Cluster Observations - GC Relative Density*

We define a function called "GC Relative Density" as the ratio of a globular cluster's density to the density it would have if it was on an extrapolation of the dashed line in Figure 15 with the same radius. GC Relative Density gives an indication of each globular cluster's displacement perpendicular to the dashed line. For example all the ringed globular clusters in Figure 15 have similar GC Relative Density.

Figure 17 shows a plot of GC Relative Density against the globular cluster's perpendicular displacement from the plane of the Milky Way galaxy. Distances above or below the plane are treated as positive. It can be seen that globular clusters that are within 40 kly of the Milky Way centre show a relationship between GC Relative Density and distance from the plane. We believe that this is the first publication of the observation of that relationship.

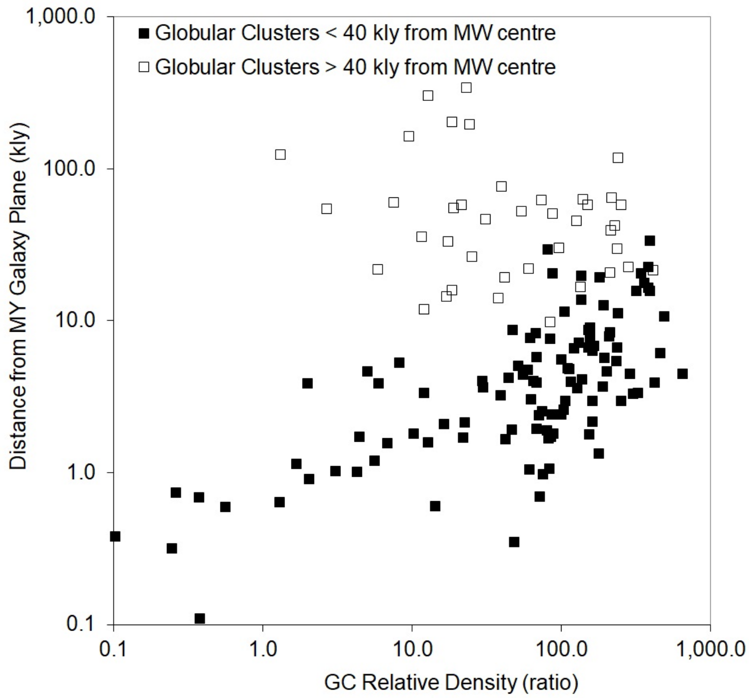

Figure 17. Globular Clusters that are within 40 kly of the Milky Way centre show a relationship between GC Relative Density and distance above or below the galaxy plane.

3.2.4. *Globular Cluster Observations - The Pulsar Retention Problem*

Globular clusters contain a high proportion of pulsars, suggesting that pulsar kicks are less likely to occur in globular clusters. (Podsiadlowski et al. 2002) This is referred to as the ”Pulsar Retention Problem”.

3.2.5. *Antigravity Matter Based Explanation of Globular Cluster Observations*

According to the Antigravity Matter hypothesis globular clusters are as described in Section 2.15 and are created by the process described in Section 2.21. They can have stars that are older than the galaxy that they are orbiting because a globular cluster is a remnant of the dense core of a previous galaxy.

The absolute value of the GC Relative Density is not particularly useful because it compares Bok globules for which the AGM Boundary is the visible surface with globular clusters for which the core’s shared AGM Boundary is somewhere within. However it is valid to observe trends in GC Relative Density between globular clusters.

Globular clusters are moving through the Antigravity Matter atmosphere as they orbit the Milky Way. They all have approximately the same orbital velocity as is common with spiral galaxies. (Rubin et al. 1980) An Antigravity Matter wind pushes their AGM Boundary inwards at the leading face and makes them denser as shown in Figure 8 and described in Section 2.15.

The Milky Way has an AGM Vortex as described in Section 2.16. Close to the galaxy plane the Antigravity Matter is orbiting the galaxy driven by the orbiting normal matter. Well away from the galaxy plane the Antigravity Matter is moving slower relative to the galaxy centre. The globular clusters in the ringed group in Figure 15 are all well away from the galaxy plane. They are therefore all moving at approximately the same speed through the Antigravity Matter.

As explained in Section 2.15 for the same wind strength, and with an assumption of geometric similarity between globular clusters, radius is proportional to the inverse square root of density. That is why the ringed group is approximately parallel to the dashed line in Figure 15.

Close to the galaxy plane the Antigravity Matter is orbiting faster than it is away from the plane. The globular cluster’s relative Antigravity Matter wind speed is lower. Therefore the globular clusters that are well away from the galaxy plane have a higher GC Relative Density than the ones that are close to the plane.

In Figure 17 there is also a small group of black globular clusters that have high GC Relative Density even though they are close to the plane. These are possibly globular clusters that are on highly inclined orbits. They pass through the plane twice per orbit. As they pass through their speed relative to the Antigravity Matter remains high and their GC Relative Density remains high.

Pulsar kicks are caused by Antigravity Matter. One mechanism for this is described in Section 2.23. Pulsar kicks do not occur in the core of globular clusters because there is no Antigravity Matter inside the shared AGM Boundary around the core. Therefore pulsars that are created in a globular cluster are likely to remain in the globular cluster.

Therefore the following observations are all consistent with the Antigravity Matter hypothesis:-

- The relationship between radius and density for ringed globular clusters in Figure 15
- The relationship between GC Relative Density and distance from the galaxy plane for the globular clusters that are within 40 kly of the Milky Way centre in Figure 17
- The Pulsar Retention Problem
- The existence of globular clusters
- Globular clusters containing stars that appear to be older than the galaxy they orbit

We are not aware of an alternative explanation for the first three of these.

3.3. *Elliptical Galaxies*

3.3.1. *Elliptical Galaxy Observations*

The mass-to-light ratio of several elliptical galaxies has been measured (Magain & Chantry 2013). It was found that the mass-to-light ratio "does not exceed the value predicted by stellar models by more than a factor of two", and "is about 1.8". It was also found that the density of [apparent] dark matter "follows that of luminous matter". That is, elliptical galaxies do not appear to have dark matter halos.

3.3.2. *Antigravity Matter Based Explanation of Elliptical Galaxy Observations*

Elliptical galaxies are as described in Section 2.15. They have no significant AGM Vortex as described in Section 2.16 because they have no significant net rotation. They have no apparent dark matter halo because they have no AGM Vortex. At a point outside the galaxy the total attraction of the galaxy is defined by Equation 6. This predicts that the total apparent gravity of all elliptical galaxies is a constant factor greater than the gravity of their normal matter content. They therefore all appear to have the same ratio of normal matter to dark matter content.

We can estimate that:-

$$\frac{{A_\mathrm{n}}^2}{GA_\mathrm{a}} \approx 0.8 \tag{33}$$

and

$$\frac{{A_\mathrm{n}}^2}{GA_\mathrm{a}} \leq 1.0 \tag{34}$$

Therefore the following observations are all consistent with the Antigravity Matter Hypothesis:-

- The consistency of the apparent ratio of dark matter to normal matter in elliptical galaxies
- The lack of apparent dark matter halos around elliptical galaxies

We are not aware of alternative explanations for these.

3.4. *Spiral Galaxies*

3.4.1. *Spiral Galaxy Observations - Shape*

Some but not all spiral galaxies have an overall shape made up of a flat rotating disc with an approximately spherical core.

Figure 18. A string of stars connecting NGC 5216 and NGC 5218 in Keenans system caused by two AGM Vortices linking up temporarily.

3.4.2. *Spiral Galaxy Observations - Apparent Dark Matter*

Orbital velocity of normal matter objects within a spiral galaxy disc are typically fairly constant over a wide range of radii. (Rubin et al. 1980) This gives the impression of there being a gravitationally attractive dark matter halo in space around the galaxy.

The apparent ratio of dark matter to normal matter in spiral galaxies is usually greater than for elliptical galaxies and is also highly variable. (Salucci et al. 1991)

3.4.3. *Spiral Galaxy Observations - Star Forming Regions*

Spiral galaxies tend to have a higher proportion of young stars in the outer regions of the disc and tend to have only old stars in the core.

3.4.4. *Spiral Galaxy Observations - Strings of Stars Connected to Spiral Galaxies*

NGC 5216 and NGC 5218 in Keenan's System are shown in Figure 18 (https://www.universetoday.com/16005/bridge-across-space-keenans-system-by-martin-winder-and-dietmar-hager/). The cores of these two spiral galaxies appear to be connected by a string of stars.

3.4.5. *Spiral Galaxy Observations - Early Galaxy Formation*

It has been found that galaxies formed far quicker in the early universe than had previously been expected.

3.4.6. *Spiral Galaxy Observations - Computer Simulations*

Many computer simulations of the development of a universe containing gravitationally attractive matter have been created. Some do not reproduce the typical shapes of spiral galaxies. (Klypin et al. 2011) (https://vimeo.com/29406342). However other such simulations do produce galaxy shapes (Guedes et al. 2011; Sijacki et al. 2012) (http://blogs.discovermagazine.com/80beats/2011/08/30/watch-this-the-most-realistic-simulation-of-spiral-galaxy-formation-to-date/#.WpAorahl_IU, https://www.youtube.com/watch?v=-ZcEDqyMbFw)

3.4.7. *Antigravity Matter Based Explanation of Spiral Galaxy Observations*

Spiral galaxies are created by the process described in Section 2.16, Section 2.18 and Section 2.21. In newly formed spiral galaxies there may be no core because insufficient stars have migrated to the central region. In old spiral galaxies most of the disc may have fallen into the core.

The apparent gravity of a dark matter halo is caused by a reduction in the density of Antigravity Matter in the AGM Vortex as described in Section 2.16. The density profile of Antigravity Matter that causes an orbital velocity that is constant and independent of radius is described in Section 2.17 and shown in Figure 11.

The strength of the AGM Vortex develops over time and decays over time and is affected by the local Antigravity Matter wind. This results in the apparent dark matter content of spiral galaxies being highly variable.

Antigravity Matter transports interstellar gas and dust outwards in the disc. New stars are formed in the outer regions of the disc and not in the core as described in Section 2.19.

An AGM Vortex can extend outwards away from the galaxy disc along the axis of rotation as described in Section 2.16. When this happens there is a reduced density of Antigravity Matter along the axis. This attracts normal matter objects like stars. The two galaxies in Figure 18 are rotating in the same direction and their two AGM Vortices have connected up in between them. The combined AGM Vortex has captured stars.

Galaxies formed quickly in the early universe because the effective gravity of normal matter was increased by the Antigravity Matter, and because AGM Drag reduced the kinetic energy of orbiting normal matter objects as described in Section 2.25.

The typical core and disc shape of a spiral galaxy is caused by Antigravity Matter as described in Section 2.16, Section 2.18 and Section 2.21. An accurate computer simulation of a universe without Antigravity Matter and without gravitationally attractive dark matter does not produce spiral galaxy shapes.

A computer simulation can be made to produce a rotating disc shape without Antigravity Matter and without gravitationally attractive dark matter by using a concept called gravitational softening (Barnes 2012). This is a mathematical technique whereby simulated gravity forces are reduced at short range. Unfortunately this makes the simulation unrealistic. We predict that if simulations of this sort are run with much reduced gravitational softening the spiral galaxy shapes will disappear.

A computer simulation can also be made to produce spiral galaxy shapes without Antigravity Matter by including a representation of gravitationally attractive dark matter. This is because as described in Section 2.10 the purported dark matter has some effects that are similar to Antigravity Matter. If this is done by simulating dark matter particles then the simulation must contain a mechanism to prevent the dark matter particles from collecting together in the same way that normal matter does.

Simulating spiral galaxy shapes is relatively easy if the effects of Antigravity Matter are included as can be seen at http://www.antigravitymatter.co.uk/Simulations.htm

Therefore the following observations are consistent with the Antigravity Matter hypothesis:-

- The typical core-and-disc shape of spiral galaxies
- The apparent existence of dark matter halos around spiral galaxies and the flat orbital velocity profile in a spiral galaxy disc
- The variability of the ratio of apparent dark matter to normal matter in spiral galaxies
- The higher proportion of young stars in the outer regions of spiral galaxy discs and the old stars in the core
- The string of stars connecting NGC 5216 and NGC 5218 in Keenans system.
- The faster than expected formation of galaxies in the early universe.
- The cited computer simulations of matter in a developing universe.

3.5. *Antigravity Matter based Analyses of Two Spiral Glaxies*

These two analyses are based on the assumption that $G = A_\mathrm{n} = A_\mathrm{a}$ as suggested below in Section 4.1.

3.5.1. *NGC224 Andromeda*

Andromeda is chosen as an example galaxy because of its proximity and because it yielded some of the first evidence for dark matter (Rubin & Ford 1970). An estimate of Andromeda's mass (including dark matter) vs radius relationship is provided in Figure 12 of that publication.

The total normal matter mass of the galaxy is taken as 4.0×10^{40} kg (2.0×10^{10} sols) (calculated from luminosity).

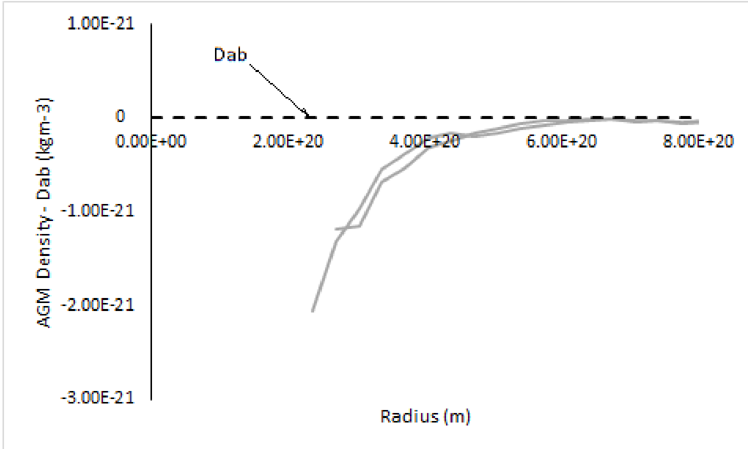

Figure 19. NGC224 Andromeda's AGM Density vs Radius Relationship from the upper and lower bounds of mass assuming $\mathrm{G} = \mathrm{A_n} = \mathrm{A_a}$. The vertical scale shows reduction in density below D_{ab}. The graph shows reduced density towards the center of the galaxy rising asymptotically to D_{ab} with increasing radius. This has the same form as the density profile shown in Figure 10.

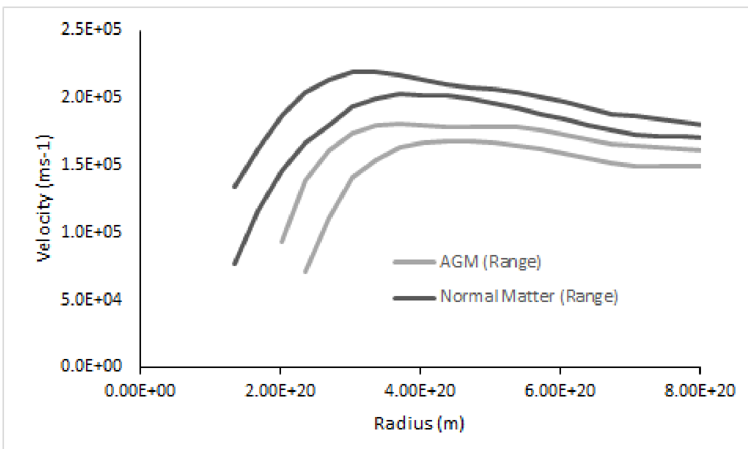

Figure 20. NGC224 Andromeda upper and lower bounds of orbital velocity for normal matter and Antigravity Matter.

The gravity of that normal matter is doubled due to its Static AGM Lacuna as explained in Equation 6. The result is an effective mass of 8.0×10^{40} kg (4×10^{10} sols) which is assumed to all be in the core for this model.

The Antigravity Matter density reduction in the Dynamic AGM Lacuna (outside the core) is calculated by inverting and transposing the apparent density of the dark matter halo, which is also treated as being spherically arranged. This step uses the principle of AGM Equivalence as described in Section 2.4. The result is shown in Figure 19.

The Antigravity Matter orbital velocity is calculated by assuming that Antigravity Matter is in a circular orbit and that it is only attracted to the Dynamic AGM Lacuna (because the effects of the normal matter in the core and its Static AGM Lacuna cancel each other out). This is shown in Figure 20.

3.5.2. *NGC3198*

The second galaxy analysed is NGC 3198. This is chosen because it is used by Sanders (1986) as a calibration galaxy as referenced in Section 5.

Basic galactic parameters are taken from SIMBAD. Distance=14mpc, apparent brightness=10.87. The total normal matter mass of the galaxy calculated from luminosity is 1.54×10^{40} kg (7.7×10^{9} sols). This is doubled according to Equation 6 to make an effective normal matter mass in the core of 3.08×10^{40} kg (1.54×10^{10} sols).

Orbital velocity data is provided by van Albada et al. (1985).

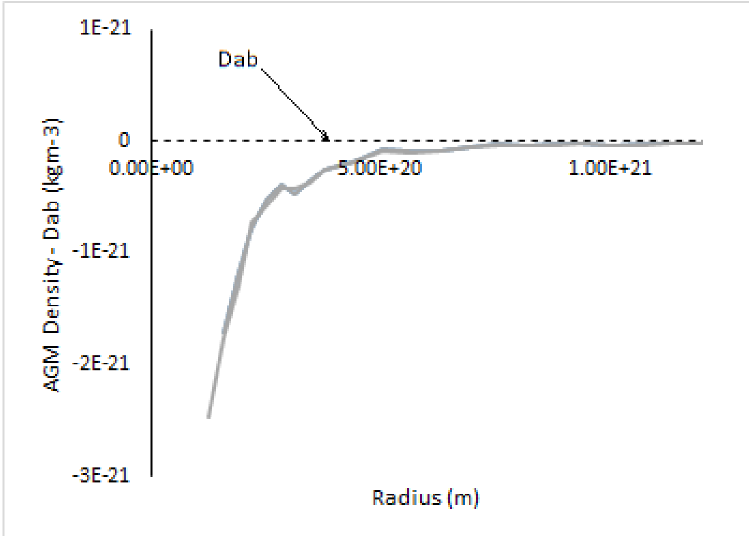

Figure 21. NGC3198's AGM Density vs Radius Relationship from the upper and lower bounds of mass assuming G = A_n = A_a. The vertical scale shows reduction in density below D_{ab}. The graph shows reduced density towards the center of the galaxy rising asymptotically to D_{ab} with increasing radius. This has the same form as the density profile shown in Figure 10.

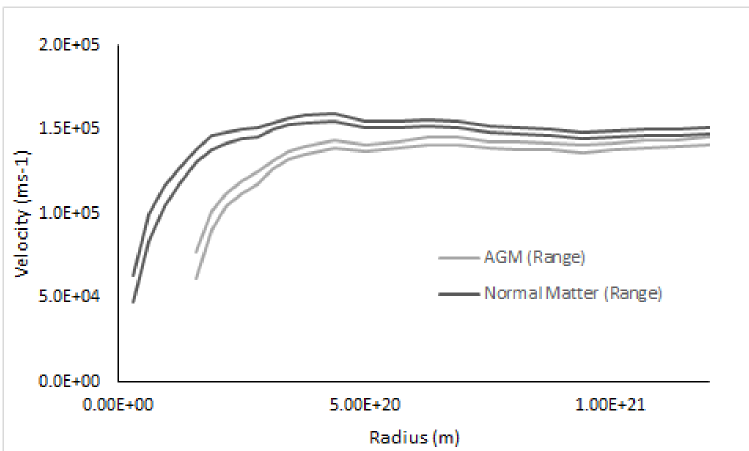

Figure 22. NGC3198 upper and lower bounds of orbital velocity for normal matter and Antigravity Matter.

The Antigravity Matter density and Antigravity Matter orbital velocity are calculated in the same way as for Andromeda. These are shown in Figure 21 and Figure 22.

3.5.3. *NGC224 Andromeda and NGC3198 Observations and Discussion*

Figure 19 and Figure 21 shows that close to the center of both galaxies the density of Antigravity Matter is reduced below Dab and as radius increases the density of Antigravity Matter increases asymptotically to Dab. These relationships are consistent with the form shown in Figure 10.

Figure 20 and Figure 22 show that for both galaxies the orbital velocity of Antigravity Matter is lower than the orbital velocity of normal matter. This is consistent with the hypothesis that the Antigravity Matter flows into the galaxy disc near the center and is accelerated by the normal matter in the disc as it flows out as described in Section 2.16.

It may be that the normal matter mass is actually significantly spread out in the disc and not all concentrated in the core as is assumed for these calculations. That is more likely in NGC 3198 which appears to have massive regions in the disc. That would have the effect of reducing the Antigravity Matter orbital velocity somewhat at low radius in

Figure 23. NGC 1300

Figure 22. Figure 21 would still show the same general shape. The result would still be consistent with the current hypothesis.

3.6. *Spiral Galaxy NGC 1300*

3.6.1. *NGC1300 Observations*

NGC 1300 is shown in Figure 23 (https://apod.nasa.gov/apod/ap160109.html). It's two outer arms form two main spirals. They are bright and textured. Each spiral consists of several smaller spiral substructures. There are dark lines marking the trailing edge of some of the spirals and separating some of the spiral substructures. The spirals are accompanied by many globular clusters of stars. At this outer radius the normal matter of the galaxy is unevenly distributed and is lumpy in appearance.

The inner region of the galaxy inside the two outer arms contains a straight galaxy bar with a core at the centre. This inner region is much more diffuse in appearance. There are few globular clusters. The bar is marked with dark lines that stretch inwards from the inner point of the two outer arms.

3.6.2. *Antigravity Matter Based Explanation of NGC1300*

NGC 1300 is an example of a spiral galaxy that is in the process of forming from two dense galaxies. It is at an early stage of the process described in Section 2.21.

The precursor galaxies were either elliptical galaxies or spiral galaxies with most of their normal matter material within their cores. The outer arms of NGC 1300 are the remains of the dense cores of the precursor galaxies. They are dense and bright. They are still mostly at their AGM Exclusion Density. Within much of the spiral arms normal matter and Antigravity Matter are not mixed.

The outer arms used to be spherical in the precursor galaxies but they are now being stretched and broken up by tidal forces and Antigravity Matter drag. They are breaking up unevenly, forming smaller collections of stars that are still at their AGM Exclusion Density. These are the spiral substructures and the globular clusters. The Antigravity Matter is being diverted around these structures as they rotate because they are so dense.

Any stars or gas and dust which are ejected from these dense structures are affected by drag from the Antigravity Matter wind caused by the rotation of the galaxy. The gas and dust is strongly affected by the drag. This material is swept backwards relative to the spiral arm. Some of it collects along the trailing edge of the spiral arm where it is partly protected from the wind. There it forms the dark lines along the trailing edges of the spiral arms and between spiral substructures.

Stars that are ejected from the spiral arms are also affected by the Antigravity Matter wind. They lose energy, fall to a lower orbit, speed up and overtake their previous position in the spiral arm. They move forwards along the outside of the spiral arm to the front of the spiral arm. Their orbits continue to decay and they fall into the inner region of the galaxy. Some of the gas and dust ejected by the spiral arms is dragged forward with these stars to the front of the spiral arms and into the inner region.

Most of the normal matter mass of the galaxy is still in the outer spiral arms. The outer arms are driving an AGM Vortex but the Antigravity Matter density profile is fairly flat in the inner region as described in Section 2.21. The overall Antigravity Matter density profile of the galaxy has the form of the two lines in Figure 11 combined. The junction between the two lines is at the inner end of the spiral arms. As a result in the inner region normal matter orbital velocity is approximately proportional to radius as described in Section 2.17. This means that a radial structure can remain radial as the galaxy rotates. The material that falls from the front of the outer arms forms a radial bar as it descends.

The stars that are falling into the inner region have become well separated from each other. They are no longer in large groups with shared AGM Boundaries. They interact chaotically and spread out as they fall to the centre. The gas and dust does not spread out and creates dark lines within the bar.

Towards the centre the bar is affected by the gravity of a small but developing core and the gas and dust lines become spirals.

In time the outer arms will be shredded by tidal effects and Antigravity Matter drag. Stars will be mixed with Antigravity Matter in the resulting smaller galaxy disc, with the exception of any remaining temporary globular clusters. Also in time more stars will collect in the centre. The density in the centre will increase as the stars lose energy to Antigravity Matter drag. Eventually a large core will form with a shared AGM Boundary.

In yet more time, if it is not disturbed the galaxy disc will all fall into the core and the spiral galaxy will become an elliptical galaxy.

Therefore the following observations are consistent with the AGM hypothesis.

- The two different textures of star groups in NGC1300 corresponding to those which are at the AGM Exclusion Density and those which are below the AGM Exclusion Density
- The globular clusters in NGC1300 located with the outer arms
- The galaxy bar in NGC 1300 consistent with an AGM Vortex being driven by the outer spiral arms
- The location of dust lanes in the inner and outer regions of NGC1300.

3.7. *Local Interstellar Cloud*

3.7.1. *Local Interstellar Cloud Observations*

Interstellar molecular matter in the vicinity of the Sun is moving away from the centre of the galaxy relative to the Sun at about $25\,\mathrm{km\,s^{-1}}$ (Frisch et al. 2013). The Sun's radial velocity relative to the centre of the galaxy is about $10\,\mathrm{km\,s^{-1}}$ inwards. (Bovy et al. 2012).

3.7.2. *Antigravity Matter Based Explanation of Local Interstellar Cloud Observations*

The interstellar molecular matter comprises low density normal matter gas and dust that is mixed with the interstellar Antigravity Matter atmosphere. The gas and dust is being transported outwards by the flow of Antigravity Matter within the Milky Way's AGM Vortex as described in Section 2.16 and shown in Figure 9. The local Antigravity Matter atmosphere and the Sun both have approximately the same tangential speed. The Sun is also moving radially inwards and the Antigravity Matter is also moving radially away from the galaxy centre at about $15\,\mathrm{km\,s^{-1}}$.

The fact that the local interstellar clouds are flowing outwards from the galaxy centre relative to the Sun is consistent with the Antigravity Matter hypothesis and the flow pattern shown in Figure 10.

The local interstellar molecular matter has a temperature of about 7000 degrees. This may be due to the fact that it has recently been ejected from a star or it may indicate that this is the temperature of the local Antigravity Matter atmosphere, which has been heated by the turbulence at the center of the galaxy and is now cooling as it is transported outwards.

3.8. *Galaxy Clusters Abell 1689 and the Bullet Cluster*

3.8.1. *Observations of Abell 1689 and the Bullet Cluster*

The graph in Figure 24 was published by Taylor et al. (1998). This shows an estimate of the cumulative total matter content of Abell 1689. It shows that beyond a visual radius of about 3 arcminutes the cumulative mass of the cluster appears to decrease with increasing distance from the centre.

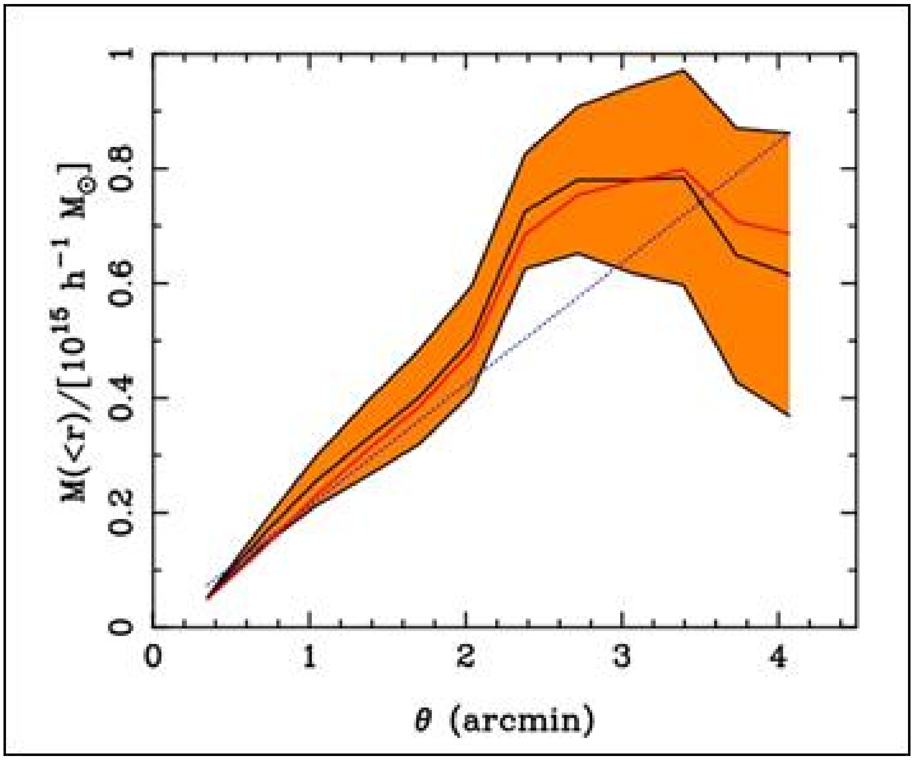

Figure 24. The cumulative apparent total mass profile of galaxy cluster Abell 1689 (Taylor et al. 1998). Beyond a radius of about 3 acrmins the cumulative mass of the galaxy appears to decrease as radius increases.

The image in Figure 25 was published by Clowe et al. (2004). This shows an estimate of the density of matter in the Bullet Cluster 1E0657-558. This shows regions of negative density around the outside of the cluster. Clowe et al. (2004) explain this as being due to the fact that the densities are relative to the density at the edges of the image. If this is interpreted using only gravitationally attractive matter then there must be a high density of matter in the centre, which is surrounded by a region of low or zero density matter, which in turn is surrounded by a region of intermediate density matter at the edges of the image.

3.8.2. *Antigravity Matter Based Explanation of Abell 1689 and the Bullet Cluster Observations*

According to the Antigravity Matter hypothesis the apparent gravity fields of the two clusters are caused by the process described in Section 2.22. The density of the Antigravity Matter atmosphere is reduced in the centre of the cluster to form an AGM Lacuna. The density of Antigravity Matter is increased in an Antihalo around the outside of the cluster. The Antihalo cancels out much of the the attraction of the AGM Lacuna and causes the apparent total mass to decrease with distance. This also gives the impression of a region of negative density dark matter.

Therefore these apparent gravity fields around Abell 1689 and the Bullet Cluster are consistent with the Antigravity Matter hypothesis. They are also evidence against any theory that depends on gravitationally attractive dark matter. We are not aware of an alternative explanation for this evidence.

3.9. *The Guitar Nebula*

3.9.1. *Observations of the Guitar Nebula*

The Guitar Nebula is shown on the right of Figure 26. It is approximately 1.5 ly long. At the head of the guitar is a fast moving slow spinning neutron star, PSR 2224 + 65. (Chatterjee & Cordes 2002)

3.9.2. *Antigravity Matter Based Explanation of the Guitar Nebula Observations*

Pulsar kicks are caused by Antigravity Matter. The Guitar Nebula has been created by the process described in Section 2.23 and shown in Figure 12. Its shape is as built up in the left side of Figure 26.

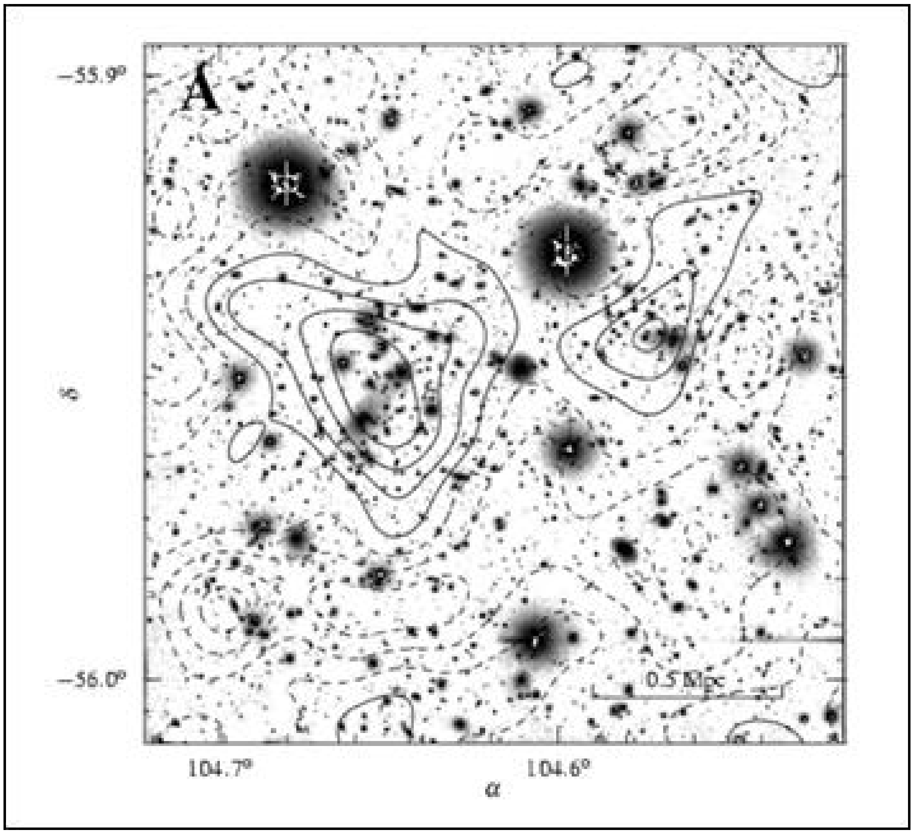

Figure 25. A weak lensing mass reconstruction of the Bullet Cluster with solid black contours for positive mass and dashed contours for negative mass. (Clowe et al. 2004)

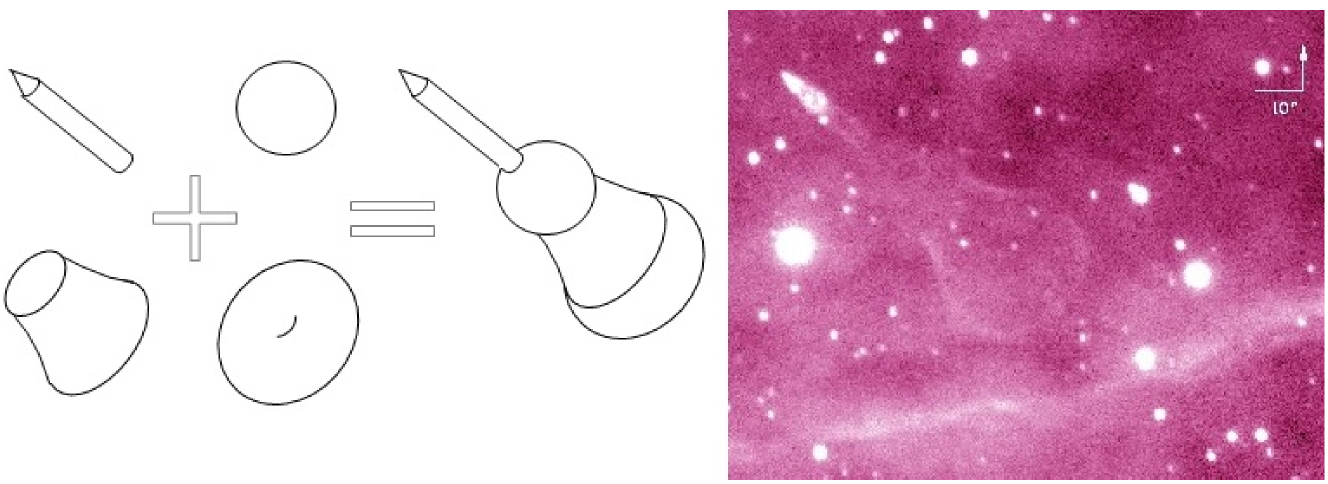

Figure 26. The Guitar Nebula demonstrating the pulsar kick process shown in Figure 12

From the location and speed of the pulsar we estimated that the kick occurred around 150 years ago. The supernova was many years before that. It should be possible with currently available technology to observe that the toroidal vortex is moving in the opposite direction to the pulsar relative to the central ball.

Therefore the following observations are consistent with the AGM hypothesis:-

- Pulsar kicks
- The shape of the Guitar Nebula.

We are not aware of an alternative explanation for the first of these.

3.10. *Dark Matter Density*

3.10.1. *Observations of Dark Matter Density*

Unlike normal matter, gravitationally attractive dark matter remains at low density and does not appear to fall towards its centre of gravity.

3.10.2. *Antigravity Matter Based Explanation of Dark Matter Density Observations*

The effects attributed to gravitationally attractive dark matter are actually caused by a reduction in density of Antigravity Matter. The density of Antigravity Matter cannot go below zero so this puts a top limit on the possible apparent density of gravitationally attractive dark matter.

Therefore the fact that dark matter appears to remain at low density is consistent with the Antigravity Matter hypothesis.

3.11. *Dark Matter Detection on Earth*

3.11.1. *Observations*

Many attempts have been made and are being made to detect dark matter directly by means that do not depend on gravity. However no dark matter particles have ever been conclusively detected.

3.11.2. *Antigravity Matter Based Explanation of Dark Matter Detection Observations*

According to the Antigravity Matter hypothesis in Section 2 there is no gravitationally attractive dark matter. Instead the universe contains a thin atmosphere of Antigravity Matter. The nearest significant density of Antigravity Matter is a long way away from the Earth.

Therefore the non-detection of dark matter on Earth is consistent with the Antigravity Matter hypothesis. We predict that experiments to detect dark matter directly on Earth will continue to produce negative results.

3.12. *Cosmic Microwave Background Acoustic Peaks*

3.12.1. *Observations*

Acoustic peaks have been detected in the Cosmic Microwave Background ("CMB") (Torbet et al. 1999; Melchiorri et al. 2000; Hanany et al. 2000). These have been attributed to the interaction between dark matter, photons and baryons in the early universe. (Peebles & Yu 1970; Sunyaev & Zeldovich 1970)

3.12.2. *Antigravity Matter Based Explanation of CMB Observations*

As explained in Section 2.24 in the proposed process that created the CMB gravitationally attractive dark matter can be replaced by Antigravity Matter with no visible change to the outcome. Therefore if observations of acoustic peaks in the CMB are consistent with theories of dark matter they are also consistent with the Antigravity Matter hypothesis.

3.13. *Baryonic Acoustic Oscillation and Galaxy Distribution*

3.13.1. *Observations*

A Baryonic Acoustic Oscillation ("BAO") signal has been detected. (Eisenstein et al. 2005) It has been attributed to the collapse of slightly over-dense regions of normal matter and dark matter at the time of recombination due to gravity. (Peebles & Yu 1970; Sunyaev & Zeldovich 1970).

On a smaller scale than the BAO, galaxies are arranged in clusters and formations of sheets and strings separated by vast approximately spherical spaces with little observable matter. (Freedman & Kaufmann 2001).

3.13.2. *Antigravity Matter Based Explanation of BAO Observations*

The process by which galaxies have formed since recombination is described in Section 2.25.

Therefore the following observations are consistent with the Antigravity Matter hypothesis:-

- The BAO signal
- The arrangement of galaxies in clusters and formations of sheets and strings separated by vast approximately spherical spaces with little observable matter

3.14. *More Evidence*

More evidence for the existence of Antigravity Matter is available at www.antigravitymatter.co.uk.

4. ESTIMATES OF ANTIGRAVITY MATTER PARAMETERS

4.1. *An Estimate of A_n and A_a from Spiral Galaxies*

Consider a normal matter object and an Antigravity Matter particle that are both orbiting a spiral galaxy at its outer radius. They are far enough apart that they do not interact with each other. We make the following assumptions:-

- The spiral galaxy has an AGM Vortex as described in Section 2.16.
- The tangential velocity of the Antigravity Matter is 80-100% of the tangential velocity of the normal matter (as suggested by the observation in Section 3.7). We introduce constant P to represent this where:-

$$0.8 \leq P \leq 1.0 \tag{35}$$

- We modify Equation 33 and Equation 34 for the purposes of this estimate such that:-

$$\frac{{A_\mathrm{n}}^2}{GA_\mathrm{a}} = Q \tag{36}$$

where

$$0.6 \leq Q \leq 1.0 \tag{37}$$

- The object and the particle are only affected by gravity and antigravity. Pressure has no effect.
- The Antigravity Matter particle is spiralling outwards and the normal matter object is spiralling inwards as shown in Figure 9 but their paths are sufficiently close to being cicular that we can ignore any radial movement and treat them as being in circular orbits.
- The mass of normal matter is M_N. This is modelled as being in the center of the galaxy.
- The Dynamic AGM Lacuna caused by the AGM Vortex is modelled as a missing mass of Antigravity Matter in the centre of the galaxy of M_L.

The normal matter object is attracted to the normal matter in the centre of the galaxy and to the Static AGM Lacunas around the other normal matter objects and to the Dynamic AGM Lacuna caused by the AGM Vortex. The Antigravity Matter particle is only attracted to the Dynamic AGM Lacuna caused by the AGM Vortex (because for the Antigravity Matter particle the other two cancel out)

The circular paths of the of the Antigravity Matter particle and the normal matter object are the same. From Equation 6:-

$$A_\mathrm{a}M_\mathrm{L} = P^2(GM_\mathrm{N}(1 + \frac{{A_\mathrm{n}}^2}{GA_\mathrm{a}}) + A_\mathrm{n}M_\mathrm{L}) \tag{38}$$

Substitute from Equation 36 to remove $\mathrm{A_a}$

$$M_\mathrm{L}\frac{A_\mathrm{n}}{G} = M_\mathrm{N}GP^2\frac{1+Q}{A_\mathrm{n}/Q - P^2G} \tag{39}$$

$M_\mathrm{L}\frac{A_\mathrm{n}}{G}$ is the amount of hypothetical gravitationally attractive dark matter that would be needed to replace and reproduce the attraction of the Dynamic AGM Lacuna caused by the AGM Vortex. More dark matter would be needed to replace the attraction of the Static AGM Lacunas around other normal matter objects. That second amount of dark matter is given by Equation 6 so that:-

$$TotalApparentAmountOfDarkMatter = M_{\mathrm{N}}(Q + GP^2 \frac{1+Q}{A_{\mathrm{n}}/Q - P^2G}) \tag{40}$$

If we estimate that the typical ratio of apparent dark matter to normal matter in a spiral galaxy is between 2 and 10 then

$$2 \leq (Q + GP^2 \frac{1+Q}{A_{\mathrm{n}}/Q - P^2G}) \leq 10 \tag{41}$$

therefore

$$0.45 \leq \frac{A_{\mathrm{n}}}{G} \leq 3.0 \tag{42}$$

$$0.34 \leq \frac{A_{\mathrm{a}}}{G} \leq 9.0 \tag{43}$$

These estimates are consistent with the common suggestion that $G = A_{\mathrm{n}} = A_{\mathrm{a}}$.

4.2. *Estimates of the Background Density of Antigravity Matter D_{ab}*

4.2.1. *An Estimate of D_{ab} from the Local Interstellar Medium.*

The local interstellar medium has a density of about $1 \times 10^{-24}\,\mathrm{kg\,m^3}$. According to the current hypothesis this detected normal matter is merely contamination within the local Antigravity Matter atmosphere as described in Section 3.7. Therefore we expect that $\mathrm{D_{ab}} \gg 1 \times 10^{-24}\,\mathrm{kg\,m^3}$.

4.2.2. *Several Estimates of D_{ab} from Spiral Galaxies*

According to the current hypothesis the Antigravity Matter atmosphere and a spiral galaxy disc both influence each other by exchanging momentum. It is unlikely that they have very dissimilar average densities.

The average density of the 100 closest stars to the Sun is about $5 \times 10^{-21}\,\mathrm{kg\,m^{-3}}$ if we assume they are all Sun-like. (http://www.recons.org/TOP100.posted.htm). However there is a great deal of variability in the density of a galaxy disc. The highest density formations are globular clusters. Taking as an example the central density of Omega Centauri we expect that $\mathrm{D_{ab}} \ll 2 \times 10^{-15}\,\mathrm{kg\,m^3}$.

Figure 19 and Figure 21 show that the greatest reduction of Antigravity Matter density in two example spiral galaxies is about $2.5 \times 10^{-21}\,\mathrm{kg\,m^3}$. However the analysis in that section was based on the assumption that $\mathrm{G} = \mathrm{A_n} = \mathrm{A_a}$. If we modify that to take into account the range of values allowed by Equation 42 we find that $\mathrm{D_{ab}} \geq 8.3 \times 10^{-22}\,\mathrm{kg\,m^3}$

4.2.3. *An Estimate of D_{ab} from the Guitar Nebula*

Evidence from the Guitar Nebula is in Section 3.9 and Figure 26. The image in that section is analysed making the following assumptions:-

- The Guitar Nebula has been formed by the process described in Section 2.23. The toroidal vortex contains a mixture of normal matter gas and dust and Antigravity Matter.
- Momentum is conserved as the pulsar is kicked one way and the toroidal vortex is kicked the other way. The ratio of the masses of the pulsar and the toroidal vortex is inversely proportional to the ratio of their respective distances from the central ball.
- The distance to the Guitar Nebula is 6500 ly.
- The maximum mass of a pulsar is 2 solar masses (Antoniadis et al. 2013; Demorest et al. 2010).

We estimate that the average density of the toroidal vortex is about $2.0 \times 10^{-17}\,\mathrm{kg\,m^{-3}}$. This figure is an upper limit for the background density of Antigravity Matter, $\mathrm{D_{ab}}$, because the estimated mass of the pulsar is an upper limit, because the vortex may still be expanding and because the vortex may contain significant amounts of normal matter.

4.2.4. *Summary of Estimates of Dab*

The estimates above are all consistent with:-

$$8.3 \times 10^{-22}\,\mathrm{kg\,m^{-3}} \leq D_{\mathrm{ab}} \leq 2.0 \times 10^{-17}\,\mathrm{kg\,m^{-3}} \tag{44}$$

4.3. *An Estimate of P_{ab}, the Background Pressure of the Antigravity Matter Atmosphere*

From Equation 32 and the estimates above we can also estimate that

$$7.5 \times 10^{-17}\,\mathrm{N\,m^{-2}} \leq P_{\mathrm{ab}} \leq 4.9 \times 10^{-12}\,\mathrm{N\,m^{-2}} \tag{45}$$

4.4. *An Estimate of Antigravity Matter Particle Mass*

If we assume that the background temperature of Antigravity Matter has a lower limit of 2.7 degrees K (as the background temperature of the universe) and an upper limit of 7000 degrees (as suggested in Section 3.7.2) then using Boyle's law :-

$$1.5 \times 10^{-28}\,\mathrm{kg} \leq AGMParticleMass \leq 7.2 \times 10^{-24}\,\mathrm{kg} \tag{46}$$

$$0.091 \leq \frac{AGMParticleMass}{ProtonMass} \leq 4300 \tag{47}$$

From this we estimate that within the background Antigravity Matter atmosphere there are between 780 and 1.3×10^{11} Antigravity Matter particles per cubic meter.

4.5. *An Estimate of Antigravity Matter Particle Mean Velocity due to Temperature*

The kinetic theory of gasses can be used to estimate that:-

$$200\,\mathrm{m\,s^{-1}} \leq MeanVelocityDueToTemperature \leq 860\,\mathrm{m\,s^{-1}} \tag{48}$$

Alternatively Equation 26 and Equation 30 can be used to estimate that:-

$$260\,\mathrm{m\,s^{-1}} \leq MeanVelocityDueToTemperature \leq 1100\,\mathrm{m\,s^{-1}} \tag{49}$$

4.6. *An Estimate of the Distance to the Nearest Antigravity Matter*

If the Sun was stationary with respect to the local Antigravity Matter, Equation 30 could be used to estimate that the radius of the Sun's AGM Boundary was about 1.2×10^{15} m. This is about 0.13 lightyears. However as stated in Section 3.7.1 the relative velocity of the local Antigravity Matter is about $25\,\mathrm{km\,s^{-1}}$. Equation 26 can therefore be used to estimate that along the approach axis (approximately in the direction of the center of the Milky Way) the closest Antigravity Matter is between 1.9×10^{11} m and 1.3×10^{12} m from the Sun. This is between 1.3 AU, and 8.8 AU from the Sun.

4.7. *Effect of Antigravity Matter within the Solar System*

With these estimates Equation 7 can be used to also estimate the local effects of Antigravity Matter. The Sun's AGM Boundary is distorted by the local Antigravity Matter wind but it is pushed inwards on one side and outwards on the other side so that the effects approximately cancel out over time.

The effective gravity of the Earth at 1×10^{7} m above the surface of the Earth is increased by the Antigravity Matter atmosphere by less than one part in 1×10^{18}. This is relevant to the gravitational redshift experiment in Section 5.2.

The effective gravity of the Sun at the radius of Mercury is increased by less than one part in 1×10^{13}. This is relevant to the Mercury perihelion experiment in Section 5.3.

The effective gravity of the Sun at the orbit of Saturn is increased by less than one part in 1×10^{9}. This is also relevant to Section 5.3.

5. OBJECTIONS TO THE ANTIGRAVITY MATTER HYPOTHESIS

Sanders (1986) has proposed that the dark matter effect may be caused by an antigravity force acting between observable objects in addition to gravity. This is different from the current hypothesis in which antigravity acts on a previously undetected form of matter, and gravity between normal matter objects is unchanged. Goldman (1986) has listed objections to the antigravity proposal by Sanders (1986). These objections do not apply to the current hypothesis as explained in the following sections.

5.1. *Eotvos-Dicke experiments*

Many experiments performed locally have established that all types of matter experience the same acceleration due to a gravity field to an accuracy of up to one part in 1×10^{12}.

This is consistent with the current hypothesis because Antigravity Matter is repelled from the Sun and the Earth so there is none on Earth that can be collected and tested. All the forms of matter that have been tested in this way are normal matter.

5.2. *Gravitational redshift experiments*

The experiment by Vessot, Levine et al. (1980) shows that the redshift produced by gravity agrees with predictions to an accuracy of one part in 1.4×10^4. In Section 4.7 we show that for that experiment the Antigravity Matter atmosphere affects the result by less than one part in 1×10^{18}.

5.3. *Mercury perihelion experiment*

In Section 4.7 we show that the Antigravity Matter atmosphere affects the Sun's gravity experienced by Mercury by less than one part in 1×10^{13}. We also show that the Antigravity Matter atmosphere affects the Sun's gravity at Saturn by less than one part in 1×10^9. Both these effects are far smaller than the current error limits on the measurement of G.

6. CONCLUSION

6.1. *Evidence Assessment*

There is much evidence that is consistent with the hypothesis that this universe contains an Antigravity Matter atmosphere and that gravitationally attractive dark matter and MOND are not required. That evidence can be categorized as follows.

6.1.1. *Evidence Unique to the Antigravity Matter Hypothesis*

There follows a list of evidence which is consistent with the Antigravity Matter hypothesis and for which we are not aware of alternative explanations.

- The relationship between Bok globule radius and density shown in Figure 14 and Figure 15 - Section 3.1
- The relationship between radius and density for ringed globular clusters in Figure 15 - Section 3.2
- The relationship between GC Relative Density and distance from the galaxy plane for the globular clusters that are within 40 kly of the Milky Way centre in Figure 17 - Section 3.2
- The Pulsar Retention Problem - Section 3.2
- The consistency of the apparent ratio of dark matter to normal matter in elliptical galaxies - Section 3.3
- The lack of apparent dark matter halos around elliptical galaxies - Section 3.3
- The profile of the apparent gravity fields around Abell 1689 and the Bullet Cluster - Section 3.8
- Pulsar kicks - Section 3.9

6.1.2. *Evidence Consistent with the Antigravity Matter Hypothesis and with Other Theories*

There follows a list of evidence which is consistent with the Antigravity Matter hypothesis but for which alternative explanations may have been offered.

- The globular nature of the surface of most Bok globules - Section 3.1
- The diffuse nature of some normal matter gas and dust in situations that correspond with Antigravity Matter wind - Section 3.1
- The existence of globular clusters - Section 3.2
- Globular clusters containing stars that appear to be older than the galaxy they orbit - Section 3.2
- The typical core-and-disc shape of spiral galaxies - Section 3.4
- The apparent existence of dark matter halos around spiral galaxies and the flat orbital velocity profile in a spiral galaxy disc - Section 3.4
- The variability of the ratio of apparent dark matter to normal matter in spiral galaxies - Section 3.4
- The higher proportion of young stars in the outer regions of spiral galaxy discs and the old stars in the core - Section 3.4
- The cited computer simulations of matter in a developing universe - Section 3.4
- The rapid formation of galaxies in the early universe - Section 3.4
- The results for NGC224 Andromeda and NGC3198 in Section 3.5 being consistent with Section 2.16.
- The two different textures of star groups in NGC1300 corresponding to those which are at the AGM Exclusion Density and those which are below the AGM Exclusion Density - Section 3.6
- The globular clusters in NGC1300 located with the outer arms - Section 3.6
- The galaxy bar in NGC 1300 consistent with an AGM Vortex being driven by the outer spiral arms - Section 3.6
- The location of dust lines in the inner and outer regions of NGC1300 - Section 3.6
- The Local Interstellar Clouds are moving away from the galaxy center as described in Section 3.7.
- The shape of the Guitar Nebula - Section 3.9
- Dark matter remaining at low density - Section 3.10
- The non-detection of dark matter on earth - Section 3.11
- The CMB anisotropies - Section 3.12
- The BAO signal - Section 3.13
- The arrangement of galaxies in clusters and formations of sheets and strings separated by vast approximately spherical spaces with little observable matter - Section 3.13

6.1.3. *Evidence Inconsistent with Gravitationally Attractive Dark Matter*

Evidence has been identified which is inconsistent with any theory of gravitationally attractive dark matter but consistent with the Antigravity Matter hypothesis.

- The apparent gravity fields around Abell 1689 and the Bullet Cluster - Section 3.8

6.2. *Opportunities to Collect Further Evidence*

We predict that futher evidence for the Antigravity Matter hypothesis can be collected as follows.

- A large scale computer simulation that starts with mixed normal matter and Antigravity Matter will generate normal matter shapes of spiral galaxies, barred spiral galaxies, reverse spirals, lenticular galaxies, elliptical galaxies and globular clusters. The galaxies will be arranged in clusters of and formations of sheets and strings with large approximately spherical spaces between.
- Most Bok globules will be found to follow the trend described in Section 3.1.2 as long as distance estimates are calculated using Bonnor-Ebert modelling or simillar.
- Observations of the Guitar Nebula will show that the toroidal vortex is moving in the opposite direction to the pulsar relative to the central ball.
- The apparent distribution of gravitationally attractive dark matter around more spiral galaxies will be found to be consistent with Figure 10.
- More Antihalos will be found to exist around spiral galaxies and galaxy clusters that cancel out the effect of the apparent dark matter halo.
- Attempts to detect dark matter on earth will continue to produce negative results.
- It will be found that there is an upper to limit to the apparent density of dark matter. The upper limit is the apparent density in the center of elliptical galaxies, globular clusters and some spiral galaxies. This is because the effect is actually caused by a reduction in the density of Antigravity Matter, which cannot go below zero.
- The number of relic neutrinos (created by the birth of the universe) has been estimated as 300 particles per cubic centimeter. This is within the range identified in Section 4.4 for Antigravity Matter. We wonder if Antigravity Matter is related to relic neutinos. The mass of a neutrino has previously been constrained to below 2.14×10^{-37} kg because if it was higher its gravity would have collapsed the universe. However if relic neutrinos are or have become Antigravity Matter that constraint does not apply and they may be driving the expansion of the universe.
- Investigation of dark energy may demonstrate that Antigravity Matter at least partially explains the expansion of the universe.

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Table 1. Change History

Date	Version	Notes
3rd March 2018	1.00	Investigation webpage superseded by Repulsive Dark Matter paper on www.antigravitymatter.co.uk
9th April 2018	1.01	Repulsive Dark Matter renamed back to Antigraviy Matter
23rd January 2023	1.02	Clarify Bok globule data source; Correct Antihalo prediction statement; Add sections on Andromeda and NGC 3198; Extend section on estimates; Add sections on objections; etc
22nd June 2023	1.03	Limit scope of Equation 19, Acknowledge the heating of Antigravity Matter within a spiral galaxy and a galaxy cluster. Change estimate of particle mass. Add estimates of particle velocity due to temperature.